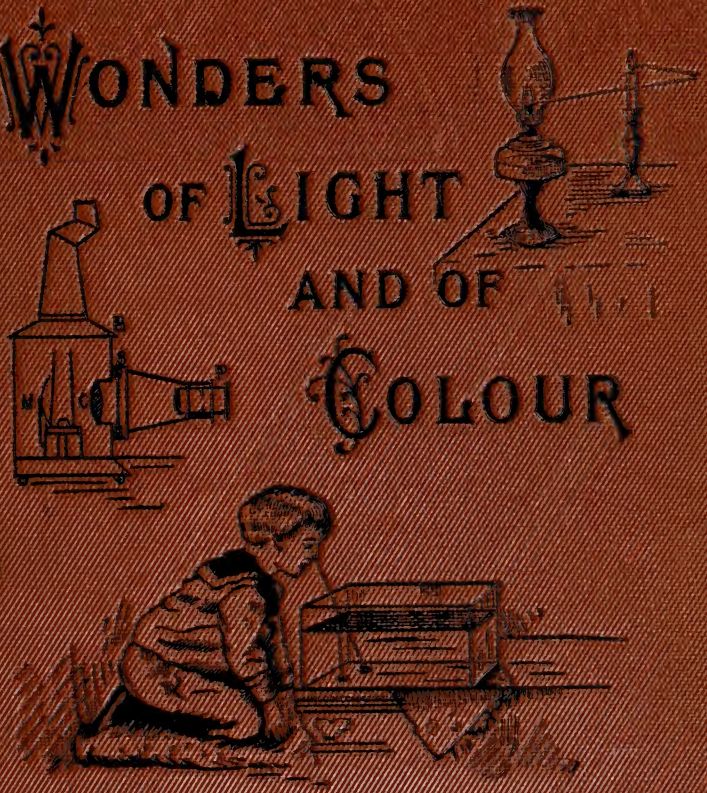
WONDERS OF LIGHT AND OF COLOUR



April 20th 1924

Awarded

to

For regular attendance
at Sunday School
With love from
his teacher. E. B. Pattison

Chapters on
Photography
Camera Lucida
Stereoscope etc

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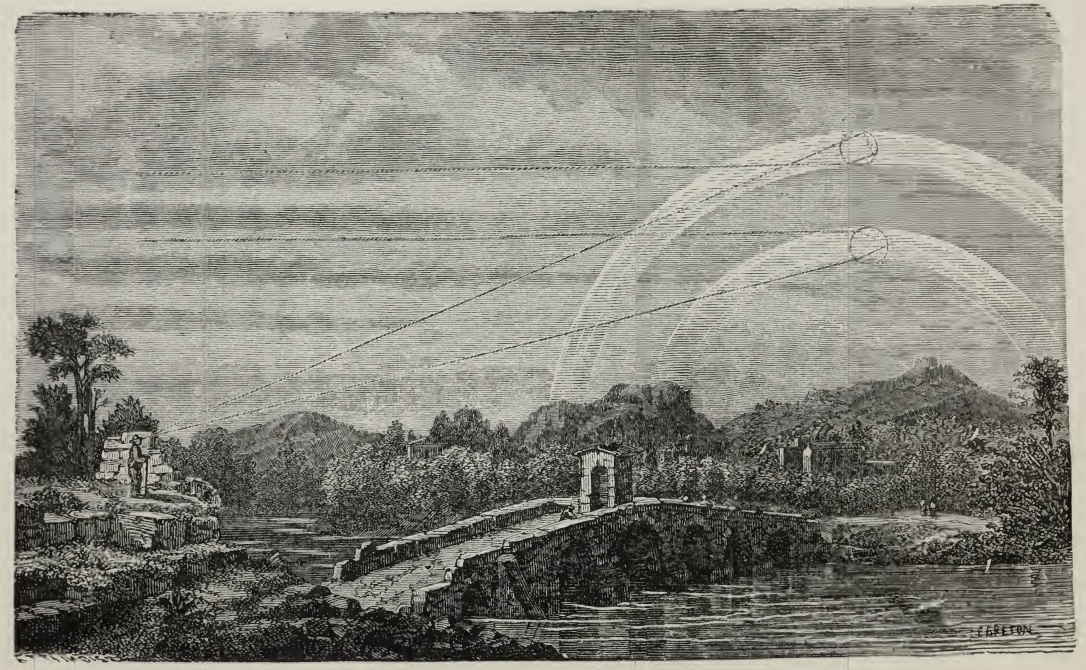

THE RAINBOW.

WONDERS

OF

LIGHT AND OF COLOUR.

"God said, Let there be light: and there was light. And God saw that it was good." (Genesis i. 3, 4.)

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CONCLUSION.

WONDERS OF LIGHT AND OF COLOUR.

EVENING I.

ON a former occasion we considered a little as to what was the meaning of science, and saw that it was simply 'knowledge,' and especially knowledge concerning things we see, hear, smell, taste, and handle—things that are all around us: anything on which we can exercise one or more of our five senses.

God has given us these senses, and in His wisdom has made the things around us to suit and adapt themselves to those senses. We use them so constantly that we are apt to overlook their importance. But the moment we lose any one of them, or they become impaired, we are conscious of their value directly, and find it very inconvenient to do without any one of them.

Watch, for instance, the deaf and dumb 'talking' together on their fingers, if indeed we can call it talking. They have voices and could speak as well as other people if they only knew how to use the voice, and what to call things. They are able to learn that K N I F E spells knife, and they know what a

knife is and how to use it, because they can *see* how it is used by others. But they do not know what to call it, because they are deaf and cannot hear what it is called by others. Thus we see that they are dumb because they cannot hear: they are deprived from birth of one of the five senses with which most are blessed, and are consequently debarred from many of the pleasures we enjoy.

What a mercy it is that they are able to be taught to read, and can thus read the Bible; and can write, and 'talk' to one another on their fingers, and by a multitude of signs can convey what they mean.

Indeed, some are very clever in making and understanding signs. I remember that once a foreign deaf and dumb gentleman delivered an address to a number of deaf and dumb persons in London though he did not understand English. He could not *spell* in English any of the words on his fingers, and yet he was able by a multitude of signs to deliver an address, which was understood by many if not by all who saw him.

We may be quite sure that such persons need much careful teaching and training before they could communicate their thoughts by signs only. It has often been remarked that when persons are deprived of one of the senses, they seem to have greater power and acuteness in using some of the others. Thus a blind person can often *feel* very acutely: a blind woman may sometimes be seen threading a needle more easily than some could do it who have their eyesight.

Let us, then, value all our senses as the gifts of

God to us. The one that seems the most valuable is the power of seeing, and yet how many there are that do not make such use of their eyes as they might do: they pass by the beautiful things in nature without a thought of their loveliness.

How many people admire fine clothing, and strive to obtain it, and yet our Lord said, "Consider the lilies, how they grow: they toil not, they spin not: and yet I say unto you, that Solomon in all his glory was not arrayed like one of these." (Luke xii. 27.) Only think of it, that all Solomon's fine apparel was not equal in elegance to a simple field lily. Are you unable to see the truth of this comparison? take a microscope, and the finest linen will look like sackcloth, and you will see how very uneven and irregular it is. Then put a lily in the microscope, and the stronger the power the more beauties will be seen: everything is regular and perfect. Yes, it does indeed excel the finest clothing that was ever made by man.

Let us learn to use our eyes, then, and without any magnifying glass there are thousands of wonders to be seen in all the works of God. Look, for instance, at the trees, and see what a vast multitude of different kinds there are, and no two are exactly alike; and yet they are all formed of *three parts:* roots, leaves, and branches (including the trunk), and nearly the whole having but two colours: green and brown. Every leaf is wonderfully made, with powers somewhat like our lungs, our skin, and our stomach: indeed, some few plants even catch insects and feed upon them. Have you noticed that when God spoke of Solomon

being wiser than all other men, He recorded that "he spake of trees from the cedar-tree that is in Lebanon even unto the hyssop that springeth out of the wall," as well as "of beasts, and of fowl, and of creeping things, and of fishes"? (1 Kings iv. 33.) These are things that *God* had created.

But I must not forget that Light and Colour are our subjects, and I must not wander too far from them. As we hope to see, there are many wonders connected with them, which we are all apt to overlook and forget.

On the other hand, we shall see how mistaken may be the proverb that "seeing is believing." This is far from being always true even in daily life. We may find things to be crooked that look to be straight; and things straight that look crooked. How many a thirsty traveller also is deluded by thinking he sees plenty of water in the distance, when it is only a mirage, that vanishes as he pursues it!

Such is life; with its thousands of delusions, after which men are hastening, to the neglect of God's lamp in this dark world—the word of God, which would lead them to Him who is the true Light, the Lord Jesus Christ, who coming into the world, lighteneth every man.

EVENING II.

LIGHT. THE EYE.

EVERY one, except the blind, is familiar with Light, and knows what a blessing it is. We wake in the morning, and perhaps find it is not yet light, and we go to sleep again. Then the sun appears and gives us light ; indeed, it is the chief source of light : not the exclusive source, for as evening draws near we seek for artificial light : electric light, gas, lamps, candles. There are in nature also other lights which we shall have to speak of.

We want to learn what light is ; but we might almost say that no one really knows. There are theories, however, two of which I will name. One is called the *Emissive* theory : that is, that something in very minute particles shoots out from the source, strikes against the objects, and then enters the eye. This is also called the *Corpuscular* theory, from *corpus*, a body, because very minute bodies were supposed to be sent forth or emitted. Newton held this theory ; but it is not in much favour now.

The other is called the *Vibratory* or Undulatory theory. This first supposes that there is something that can be vibrated, and this something is called luminous ether. We know that the atmosphere reaches some unknown distance upward from the earth ; above and beyond the atmosphere an ethereal medium, "infinitely elastic, and subtle," is said to exist, reaching

to the sun and stars—indeed, pervades all transparent substances. Light is supposed to be waves, vibrations, or undulations in this medium : whence the name of the theory.

There are several ways in which light and sound seem to act uniformly. If sound is conveyed by vibrations, may not light be so also : the one being in the air, and the other in the ether? Sir John Herschel calculated that the number of vibrations in light were not always the same, but an average rate would be 45,600 in an inch of ether, and in a second of time 555,000,000,000,000 vibrations would strike upon the eye! Minute indeed then they must be.

Perhaps the simplest way to illustrate the vibrations or waves is to refer to the common illustration of throwing a stone into a pond, or any piece of water with a smooth surface, when waves will proceed in every direction. If a cork is previously placed in the

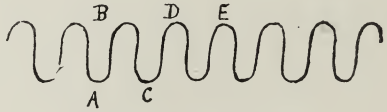


Illustration of Waves.

water, it will be seen to rise and fall with each wave that passes it. It does not travel with the waves, but simply rises and falls, nor does the water travel with the waves ; it is simply the wave-form that travels. Notice that the cork moves at right angles to the way the waves move. If the cork is at A one moment, it will be at B the next, when the water at A rises

in a wave. The length of a wave is measured from the crest of one wave to that of another, as D to E; or from hollow to hollow, as A to C.

If other vibrations could be added, exactly corresponding to those already produced, the size of the waves would be increased; but if vibrations could be so added as to bring a wave where there was a hollow, and *vice versâ*, the vibrations would be destroyed.

From this it will be seen that in light coming from any source to the eye, the ether does not travel: it is the wave-form that travels, and, as we may well suppose, the farther the wave has to travel the longer is the time occupied in the passage.

When we come to consider the question of colour, we shall find that all the various colours are bound up in a ray of light; but the waves of each colour are not of the same length, and yet all must travel in the same time. Sir John Herschel has given the size and speed of the waves for each of the colours. They are all very minute.

COLOURS OF THE SPECTRUM.	NO. OF UNDULATIONS IN AN INCH.	BILLIONS OF UNDULATIONS IN A SECOND.
Extreme red	37,640	458
Red	39,180	477
Orange	41,610	506
Yellow	44,000	535
Green	47,460	577
Blue	51,110	622
Indigo	54,070	658
Violet	57,490	699
Extreme Violet	59,750	727

It will be seen that the smaller the wave, the more there are in a second of time, so that all travel together in white light.

Numbers somewhat different from the above are given by others. Professor J. P. Cooke, of Massachusetts, estimates the dimensions of light-waves to be these:

COLOURS.	RAY.*	NO. OF WAVES IN AN INCH.
Red	A	33,417
Orange	C	38,708
Yellow	D_1	43,131
Green	E	48,205
Blue	F	52,255
Indigo	G	58,971
Violet	H_1	64,011

Professor Cooke tells us how he arrived at these conclusions, but the means used are too complicated to be described here, except to say that it was by means of a sheet of glass ruled with very close lines (as many as 17,000 in an inch) ruled accurately by machinery, and then by viewing the rays of any one colour visible between those ruled lines in a spectroscope (an instrument to be explained another evening); the calculations were made by measuring the angles at which the light was visible as one part of the spectroscope was moved round.

The velocity of light was discovered in a curious manner. Römer, a Danish astronomer, about 1675, was making observations to ascertain the times of the eclipses of the moons of Jupiter, but was surprised to

* The letters refer to the place in the solar spectrum where these colours appear. See under COLOUR.

find that they did not take place uniformly. Sometimes they came sooner than at others; but there appeared to be a gradation in the variations, and this naturally led him to believe that there must be some cause for it. This was found to be, that sometimes the eclipses were viewed when the earth, in its revolution round the sun, was nearer to Jupiter than at other times. And the difference of the time of an eclipse when the earth was at its nearest to Jupiter and when at its farthest was 16 minutes 35 seconds, which was found to be the time that light took to travel the diameter of the earth's orbit. This is about 186,000,000 miles. If the number of miles is divided by 995 (the number of seconds in 16m. 35s.) the result is about 186,995 miles per second.

Experiments have been tried by making light travel a certain distance and then be reflected back again, and the time accurately measured. The results of various experiments, and of viewing the heavenly bodies, lead to the conclusion that the velocity of light is 186,660 miles per second.

We can have no conception of such marvellous speed. A cannon ball is said to travel at first 1600 feet per second; but to reach the sun, travelling at that rate, it would take more than nine years; yet God by His almighty power makes light traverse the same distance in about $8\frac{1}{4}$ minutes! Yet, swift as this is, the distance of Jupiter is so immense, that we do not see the eclipse of one of his moons till more than half an hour after it has taken place, even when the earth is nearest to the planet, and not till

fifty minutes after when we are the farthest from Jupiter. From the planet Neptune light would take four hours to reach us, and from the fixed stars a much longer time.

Our next duty is to examine the eye itself. As with the ear and sound, so here we shall see that evidently the same Creator made both the eye and light, each suited for the other. Whatever it is that enters the eye, it must be very minute, for we all know how sensitive the eye is to the least thing that touches it.

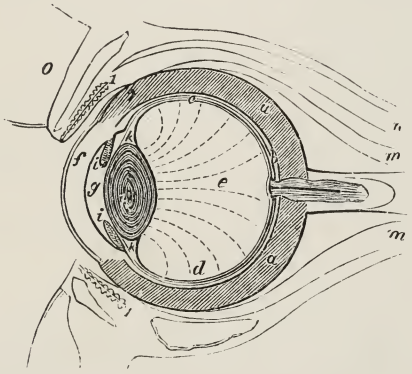
We may illustrate by a telescope what is needed in the eye, in order to fit it for its various uses. When a telescope has been used for viewing a far distant object, and then is wanted for one comparatively near, the *focus* has to be altered, that is, some of the lenses need to be moved. This is met in the eye by the crystalline lens becoming more or less convex (to be explained another evening).

Again, we need to move a telescope in all directions: upward and downward, to the right or to the left. The eyeball rests upon a cushion of fat, and has six muscles that pull the eyeball round in any direction.

The lenses of a telescope must be kept clean. To cleanse the eye, which is exposed to the atoms of dust floating in the atmosphere, there is a fluid that keeps washing it, carrying with it any minute particles of dust that may imperceptibly settle on it, aided by the motion of the eyelid. The fluid eventually finds its way into the nose, and is there evaporated by the breath.

We need to protect the lenses with a cover. Besides the eyelash, the eye also has a cover in the eyelid, which involuntarily descends and ascends so quickly as not to obscure our sight. It is the "twinkling of the eye" we read of in scripture, and is much shorter than a moment. The lid also protects the eye when we sleep.

Thus we see how inventors of the telescope have copied from their Creator, but their work is far from being as perfect.*



The Human Eye.

The front part of the eye, called the cornea (*f*), is let into the sclerotic coat, or *white* of the eye (*a*); behind the cornea is the iris (*i i*), which is the part that gives *colour* to the eye. At the back of the iris is the crystalline lens (*k k*).

* Writers on science often speak of the eye as *not* being perfect, but they seem to forget that the eye has to act as a telescope, a microscope, and for ordinary vision, things which no single instrument can possibly accomplish.

At the back of the ball (or vitreous humour, *e*, which is formed of a semi-fluid) is received on the retina (*b*) an image of what the eye sees ; but, curiously enough, the image is *inverted*, or upside down. It must be thus, because the light comes through the crystalline lens, which is double convex, and inverts any image that is seen through it at the distance of the retina. The image is conveyed to the brain by the optic nerve at the back. The brain must in some way see things upright and not inverted, perhaps by constant use, or by knowing that the things are *not* inverted. *m n* are the muscles by which the eye is moved ; *o* is the eyelid ; *g* is aqueous humour.

Besides the general knowledge that a double convex lens inverts an image, the inverted image has been seen by extracting and examining a dead bullock's eye, and viewing an object through it.

Experiment with Water Bottle.

A very simple experiment will also shew the same thing. Place a lighted candle before a clear,

round water bottle, filled with water, and on a sheet of paper, placed at the other side of the bottle, an inverted image of the flame will be seen.

If we place a candle between our eye and the water bottle, we can see distinctly *two* images: at the near surface of the bottle we see an image of the candle, *direct* or upright, and another image apparently inside the bottle *inverted.* The latter is a reflection from the interior surface of the bottle, which is concave; and the other from the outer surface, which is convex.

It must be understood that when I say that a convex lens inverts an image, I mean when it is at a proper distance for the rays to cross, not when it is close to an object, as when we use a reading glass.

Use of Reading Glass.

We may learn still more from the water bottle and a candle. We find that to get a clear image of the candle on the paper, the bottle and the candle must be a certain distance from each other,

and the image may be made clearer by placing a card with a hole in it nearer to the bottle, between the candle and the bottle, to act as the iris of the eye. When we have obtained this clear image, it represents our eye seeing an object at that particular distance. But if we move the candle further off, the image becomes indistinct, and the question is how is it to be made clear and sharp? We can only do this by moving the bottle (as in a telescope we move some of the lenses in or out); but as the bottle represents the eyeball, which we cannot move backwards and forwards, we learn that in the eye there must be some contrivance to enable it to see things at different distances clearly and distinctly. This is effected, as we have said, by altering the *shape* of the crystalline lens. By a certain muscle we are able to make this lens more or less convex, to suit the distance of the object looked at. The more distant the object, the less convex must be the lens. This alteration in the shape of the lens takes place unconsciously, without our being aware of it. For instance, if we are reading, and cast our eye upon a distant object, the lens alters instantly, and it alters back when we resume our reading. Who but the almighty Creator could have made such a wonderfully elastic lens, and caused it to act so marvellously?

This change being made so unconsciously causes some to scarcely credit it, and doubt if there is any need for it. A study of the laws of optics shews, however, the necessity of some change, for the focus of a lens depends upon its convexity. Other things

have been suggested as causing it, but are not so satisfactory as the above. That some alteration does occur can be made clear by sticking into a piece of wood two stout darning needles, one about six inches from the end, and the other eighteen inches. Place the eye at the end spoken of, so that both needles are seen. If the eyes are fixed on the distant needle till it becomes quite clear and distinct, the near one will appear indistinct; and if the near one is specially looked at (it will require a slight effort to see it at once distinctly) then the distant one will look blurred. We cannot see both needles clearly at the same time, therefore there must be some change in the eye to see distinctly objects at different distances.

These needles will also prove that the image on the retina is not the same in both eyes. If we place the piece of wood opposite to our nose, and look with the left eye only, the nearest needle will appear to the *right* of the other; but if we look with the right eye it will appear to the *left*. Yet, in some wonderful way, only one image is conveyed to the brain, though we see differently with each eye.

There is also a beautiful contrivance by which the amount of light entering the eye is regulated by the pupil (the black part in the centre of the eye) expanding or contracting, and the iris doing the same thing conversely. If we go out of the light into a nearly dark room we seem in total darkness, but the pupil expands, and we soon begin to see the objects. If we go suddenly into a well-lighted

room, the light is painful, but the pupil contracts, and we soon get used to the change.

There are very minute rods and cones which cover every part of the retina of the eye, except where the optic nerve enters, and, curiously enough, at that spot there is no sight: it is called the *blind spot* in the eye. This may be discovered by marking with a BB lead pencil two small black discs on a sheet of white paper, about three inches apart and held horizontally. If the left eye is now closed, and the left-hand disc is looked at stedfastly (but so as to see also the right-hand disc), and the head is gradually drawn backward, a place will be reached where the right-hand disc becomes invisible; and if we recede still farther it will again be seen. On moving the head nearer to the paper the same place will again be passed where the blind spot is reached. The same thing may be witnessed by the other eye, shewing that both eyes have the blind spot; but in the usual way no notice is taken of this, because when using both eyes, an object does not fall on that spot in *both* eyes at the same time.

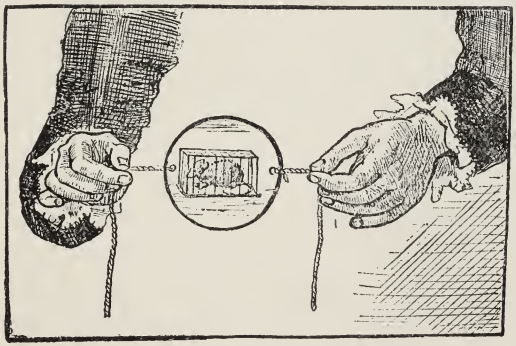
We cannot see things separately that happen very quickly: upon an average the eighth part of a second must intervene between the events, otherwise the images will mingle together. This is because every image is *retained* on the retina for the above-named period. A very easy experiment will prove this. If anything bright is fastened to a string, and whirled round rapidly, a complete bright *circle* will be seen, though we are sure that the object looked at cannot

really be at more than one part of the circle at a time, though the appearance is so different.

W N E S F I H

O D R O L G T

Or if we print on a card the letters as here arranged, seven letters on each side (the heads of the letters on the one side being towards the opposite edge of the card), and attach a cord to the two ends. By taking a cord in each hand and twirling the card round rapidly, the letters will all fall into their places and appear as if they were all written on *one* side



of the card. Or a mouse can be drawn on one side of a card, and a cage on the other, when the card is rotated the mouse will appear to be *in* the cage.*

* These are called "Thaumatropes," from the Greek *thauma*, a wonder, and *trepo*, to turn.

Series of sketches can also be made, such as a girl skipping, with the position of the rope and her arms and feet a little changed in each, till brought back to the same position. If the sketches be arranged near the outer part of a large circle of cardboard, and turned round rapidly, the girl will appear to be skipping.

The figures are sometimes arranged inside a narrow circle of cardboard, with slits between the figures, through which they are seen, and the circle turned rapidly. In another arrangement small pieces of looking-glass are fixed round the centre on which the whole moves, and the figures are seen in these glasses without having to look through slits.

These are merely toys, though they have fine names.* They however prove that the eye retains an image for a short time before it is ready to receive another and separate one. This retention of the image is called the "persistence of visual impressions."

As people get old, and from much use of the eyes, the crystalline lens gets flattened, small objects and small type are not clearly imprinted on the retina, and consequently are imperfectly seen. To remedy this, a pair of spectacles, a little convex, enable such persons to see things clearly.

Other people are said to be short-sighted, some even from birth. With these the crystalline lens is

* Zoetropes, Praxinoscopes, and Phenakistoscopes.

too convex, and they have to hold a book quite close to their eyes, and cannot see distinctly anything at a distance. To help these, a pair of spectacles with *concave* lenses have to be worn. We often see such people pull off their spectacles to read a book, and put them on to walk in the street, &c.

Sometimes it is found that a person's two eyes differ, so that they are obliged to have spectacles made on purpose, with a different lens to suit each eye. It is a great blessing to be able to read after the sight has become defective by old age ; and a knowledge of God's laws enables opticians to make glasses to suit all eyes. Where there is any peculiarity in the sight, a skilled person should be chosen to make the spectacles, because damage may be done by using wrong glasses. And the glasses should always be the same width apart as the eyes.

We see, then, that though God has in His wisdom made the eye so wonderfully to suit all needed purposes, yet there are defects in many eyes ; but these are the exceptions, and let us never forget that sin has come into the world, and has in many ways spoiled the fair, beautiful, and perfect, works of God in creation, and which He declared at first to be good, yea, very good.

EVENING III.

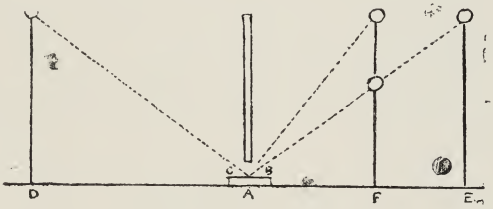
REFLECTION—REFRACTION.

WE are all more or less acquainted with what reflection is. When we are before a looking-glass we see our own face *reflected.* The light that strikes our face is scattered in every direction. If I am a speaker in a large room, those to the right and to the left can see my face as well as those at a distance ; but if a looking-glass is interposed, the rays of light, instead of travelling to the end of the room, strike the glass and are reflected back to myself.

The reflection seen in a looking-glass appears as far *behind* the glass as the object is *before* the glass. If you stand at a distance from a glass and gradually approach it, the reflection also will seem to approach the glass from behind.

There is a law in reflection that is very important,

it is that *the angle of incidence* is always equal to the angle of reflection.* I will explain this. Suppose we lay a small looking-glass on the floor, if I stand directly over it, I shall see my own face; but if I move away from the perpendicular, I shall no longer see my face. I may see some other person's face if such there be in the room; but if he is the same height as myself, he must be at the same distance from the glass on the one side as I am on the other. If he is shorter than I am, he must be closer; and if he is taller he must be farther away, or I could not see his face.



A represents the looking-glass; a person is standing at D, if another person standing at E is the same height, they will see each other's faces, because E is the same distance from A as D is; or if a short person was standing at F, he would see the face of the one at D, and the one at D would see his face. But if the one at E moved to F he would not be able to see the face of the one at D (because being taller, the angle would be different), nor could D see his face (unless the glass was large enough to see him at a different part of the

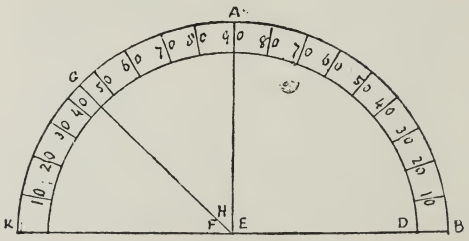
* From the Latin *incidens*, 'falling upon'

glass). If the angle of incidence is at C, it must be the same at B for the above results to follow.

I suppose you know that angles are measured by the width of the opening, and not by the length of the lines. From A to F is much shorter than from A to E, but the opening at B is the same for both, and therefore the angle is the same.

The same law of reflection applies whether the surface of the reflector is a convex or a concave part of a sphere: the two angles must be the same.

For those who do not understand anything about angles it must be explained that every circle is supposed to be divided into 360 degrees, and a right angle, embracing a quarter of a circle has 90 degrees (marked 90°); each degree is divided into 60 minutes (marked ′), and each minute is divided into 60 seconds (marked ″).



Division of Circle into degrees.

From A to B would be divided into 90 divisions, and the angle at E would be an angle of 90°, called a right angle; the inner circle would also be divided into 90 parts, so that the angle at E is precisely the same; lengthening the lines does not alter the opening at

E. If a line is drawn from E to G, midway between A and K, the angle of 90° will be equally divided, and the angle at F and the angle at H will be each 45°. An angle is said to be *acute* when it is less than a right angle, and *obtuse* when it is more than a right angle.

Where it is an angle only without any part of a circle, as in the figure on page 29, the angle would be measured in precisely the same way: a circle is always *supposed*, and its circumference is always divided into 360°, and a small circle contains as many degrees as a larger one, but of course the degrees are smaller. For many purposes it is useful to know how angles are measured.

The effect of reflected light is sometimes very curious. When the sun is low down, as in the evening, and we are facing a long row of houses, we see a reflection of the sun in perhaps the windows of *one* of the houses only—all the others are comparatively dark. As we walk along, the windows in another house shine, and the first we saw become dark; and thus as we walk the glare seems to move along before us. The truth is that the sun is shining on all the windows alike, but the angle of incidence being the same as the angle of reflection, we only see it when we come to the same angle as is formed by the windows and the sun. You can easily see the same thing by looking at the reflection of a lamp or candle in a looking-glass: as you move, the reflection of the candle will seem to move in the glass.

Reflection is an important thing in nature. In one

sense we see nearly every thing by reflection. The rays or waves of light strike an object and then come to the eye ; but when the sun itself shines we are able to see it without any reflection : the rays come to us direct, as they do also from a lamp or candle. With the moon and the planets it is different. They have no light of their own : we see them by the reflection of the light from the sun shining upon them, and then coming to us. As we might expect, the light from them is much less intense than that from the sun.

This tells us that things absorb a part of the light that shines upon them ; and some things absorb a great deal more than others. A dark piece of cloth, for instance, absorbs a great deal of light, whereas a bright piece of brass absorbs very little, and consequently looks much brighter.

We read in scripture of looking-glasses, but these were not made of glass. In Job xxxvii. 18 it is a *molten* looking-glass ; and the laver of *brass* in the tabernacle was made of the women's looking-glasses, shewing that polished metal was used very early for looking-glasses, because they absorbed but little of the light. Clear water makes a very good reflector, and many of the uncivilised still use it as a looking-glass. At times when viewing a cluster of trees at the edge of clear water it is very difficult to say where the direct sight of the trees ends and where the reflection begins.

In the streets, after the shops are closed, where no shutters are used, a very clear reflection may be seen of the passers by. The more light there is on the

outside and the darker the inside the clearer will be the reflection. If a person did not know it was a reflection, he might easily be deceived; and if a person was standing inside the shop, by a suitable action, he might appear to strike the one that is only a reflection. There is no doubt that in former days great deception was practised by means of the mirror. Thus, if an opening were made in the side of a room, and a sheet of plain glass filled the space, with a mirror placed diagonally behind it, any one approaching the mirror at the proper angle would be seen in the opening, and would appear to come nearer and nearer.

Sir David Brewster relates that when the emperor Basil of Macedonia was inconsolable on account of the loss of his son, he had recourse to the monk, Theodore Santabaren, who was supposed to work miracles. The "ecclesiastical conjuror," as Sir David calls him, exhibited to the emperor the image of his beloved son, magnificently dressed and mounted on a superb charger. The youth rushed towards his father, threw himself into his arms, and disappeared. It must have been an aërial image, or reflection, that the emperor saw. The one hidden approached the mirror, threw open his arms, and disappeared, that is, if the deception was carried out exactly in this way, which of course is not known now.

It is not difficult to make a writing appear on the wall of a room if there is a window opposite; it can be done simply by the words being written in gold,

and a bright light thrown upon them. This also has been used as a means of deception.

By a large sheet of plain glass used as a reflector, anything in one room well-lighted may be made to appear in another, as has been above described in the shop windows at night.

A very curious effect of reflection is seen in a room where two looking-glasses face each other and a chandelier is hanging in the centre. The reflection in one glass is thrown on to the other, and again reflected back to the first, and so on an indefinite number of times. By standing on one side a quantity of chandeliers apparently are seen as if you were looking down a very long passage.

Very mysterious reflections are at times seen in the air caused by some unknown state of the atmosphere. There is one known as the SPECTRE OF THE BROCKEN. The Brocken is one of the loftiest of the Hartz mountains, in Hanover. M. Haue had been there thirty times before he was favoured with the sight. On May 23rd, 1797, "about a quarter past four, he went towards the inn, and looked round to see whether the atmosphere would afford him a free prospect towards the south-west, when he observed at a very great distance, towards Achtermannshohe, a human figure of a monstrous size. His hat, having been almost carried away by a violent gust of wind, he suddenly raised his hand to his head, to protect his hat, and the colossal figure did the same. He immediately made another movement by bending his body—an action which was

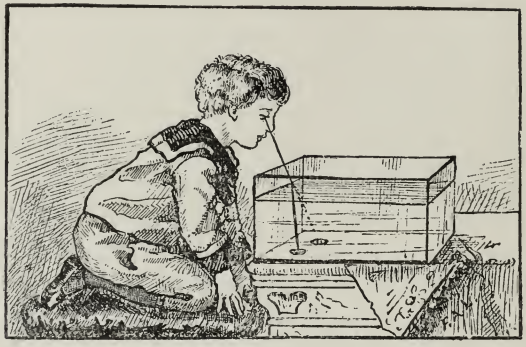
repeated by the spectral figure." Then the figure disappeared; but was again seen; and when the innkeeper joined him they were both represented by huge figures which imitated all they did; and for a short time a *third* figure appeared. The sun was behind them, and these spectral figures were reflections, or rather shadows, of themselves on some dense vapour of thin fleecy clouds. The third person seen was perhaps a double shadow of one of them.

The knowledge of reflection is utilised in turning the rays of light in one direction by a reflector. When a candle or lamp is lit, its light is thrown in every direction; but if a bright reflector is placed on one side, it turns back all the rays of light that fall upon it, and sends them in the opposite direction. Such means are of great use in lighthouses, in which no light is required on the side toward the land, but as much as possible is needed in the direction of the sea.

Strictly speaking, an object that reflects the light of another object is not *a light*, but is a reflector; but still they are often accounted as lights, as, indeed, God calls the moon a light in Genesis i. 16, though we know, by an eclipse of the moon, that it only shines or appears bright by the light of the sun being reflected from it. Thus God, in His wisdom, gives us light at night by the moon when the sun is hidden from us by the earth.

REFRACTION.

Refraction* is a curious law respecting light. As reflection means a *turning back* of the rays, so refraction means a *bending* of the rays of light by angles more or less acute. A most simple experiment will prove this law. Take a common jampot, or any



open vessel, and place in the bottom a coin. Look down so as to see the coin, now move gradually backward till you lose sight of the coin, and stand there. Let some one now pour water into the pot, and the coin will become visible to you. The explanation is this: rays of light entering a denser or a thinner medium obliquely are bent out of a straight line. In this case the rays from the coin on coming to a thinner medium (air being thinner than water) are bent, and so meet your eye when in a straight line they could not reach you. A long lead pencil, held partially in water, will look quite bent

* From the Latin *refringere*, to break back or again; but refraction is *bending* rather than breaking.

from the same cause: part is seen direct and part by refraction. A little experiment will make this much plainer than can be done in words.

We have already spoken of some subtle medium, called luminous ether surrounding the atmosphere of the earth, and reaching to the sun and other heavenly bodies. According to the above law, if that ether is thinner than air, a ray of light coming from the sun through that medium on reaching the air would be bent out of a straight line before it reached the earth. This is what is found to be the case. When the sun rises it appears above the horizon before it has actually risen, because the rays of light are bent on entering the atmosphere.

Besides this, the ray of light is further bent *after* it enters the atmosphere, because the nearer it comes to the earth the denser is the atmosphere, so that the ray is bent almost into a slight curve because of continually meeting a denser medium until it reaches the earth.

But we must return to our experiment. If we now look straight over the vessel we see the coin exactly where it actually is, and the rays are not then bent, but come in a straight line to the eye. There is no refraction when the rays strike a different medium perpendicularly: it is only when they strike it obliquely.

It is thus when the sun is rising; as it gets higher in the heavens the angle is less, and the refraction is diminished; for it is in proportion to the angle. Thus the refraction gets less and less until the sun is over

our head and then there is no refraction at all. The rays of light come in a straight line.

Estimates have been made as to the height of the atmosphere from the earth. Some of these estimates have been obtained by studying the refraction of light when the sun rises, measured from the top of a mountain and from the level of the sea.

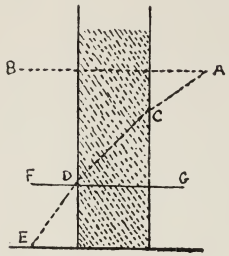
In all minute calculations as to the position of the sun, moon, or stars, in the heavens, refraction must be taken into account, and tables have been drawn up shewing the amount of refraction at various heights of objects above the horizon.

Thus at the horizon, when the thermometer is 50°, and the barometer at 29·6°, the mean refraction is 33 minutes, as given by G. F. Chambers ; and

At 1° above the horizon	24′ 29″	At 30° above the horizon	1′ 38″
„ 2 „	18 35	„ 40 „	1 8
„ 3 „	14 36	„ 50 „	0 48
„ 4 „	11 51	„ 60 „	0 33
„ 5 „	9 54	„ 70 „	0 21
„ 10 „	5 15	„ 80 „	0 10
„ 20 „	2 35	„ 90 „	0 0

To explain refraction still further, let this illustration represent a vessel of water. If a ray of light from A proceeds to B there will be no refraction, because the line is perpendicular to the sides of the water. But if the ray proceeds in the direction of C, D, E, there will be a refraction at C, and the ray will be bent downwards ; as it leaves the water it will again be bent downwards. At first sight it might seem from the above that the refraction is the same whether a

ray enters a denser medium or one more rare, because the ray bends downwards in both cases: but the



Refracted Ray.

refraction is not the same; if a line, F, G, be drawn it will be seen that the ray at C is bent *towards* that line, but from D to E it is bent *away from* that line.

As we have seen, the more oblique a ray is that strikes a medium the greater will be the refraction; and a ray may strike a medium so obliquely as not to be able to pass out on the other side at all. A simple experiment will shew this clearly. Take a wine glass and nearly fill it with water. Lay a nail across the glass, about its centre. Hold the glass high up and look *through* the water at the nail. The nail cannot be seen: the rays from the nail will be so oblique towards the eye that they cannot pass through to it.

We have mentioned that where the atmosphere is denser the refraction is greater, from which we may conclude that the greater the difference between the two mediums the greater is the refraction. Thus light passing from the air into water is not refracted as much as when it passes into glass. If air be called

1·0, water will be about 1·336, and glass be from 1·525 to 1·575, according to whether it is crown, plate, or flint glass. These are called "refractive indices" of the things named.

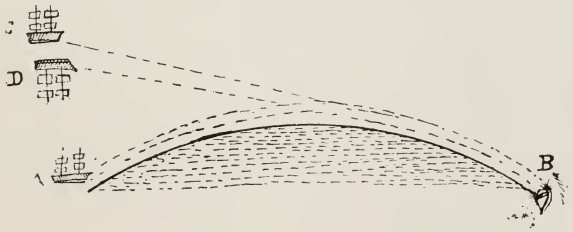
There was in 1798 quite a consternation at Hastings, on the coast of Sussex. From this town the cliffs on the French coast are distant fifty miles, and are consequently hidden by the convexity of the earth. Mr. Latham, a Fellow of the Royal Society, relates that he saw a crowd of people running towards the seashore, and was told that the coast of France could be seen by the naked eye. He hastened to the beach and, true enough, leagues of the French cliffs could be seen, and did not appear to be many miles off. The sailors could distinguish the different places they were accustomed to visit, and said that the appearance was just the same as when they sailed across and were nearing the French coast. On ascending the East cliff, by the aid of a telescope, the French boats were seen at anchor, and others in motion; and the French coast from Calais, Boulogne, etc., to St. Vallery was quite distinct. It was evening, and the view was visible till past eight o'clock. Without a doubt, refraction was the cause of this phenomenon; by some unusual state of the atmosphere the rays were bent enough to bring into view places that were below the horizon.

Near the lakes of Cumberland mysterious sights have been seen at times. In the year 1743 a gentleman and his servant "saw the figure of a man with a

dog pursuing some horses along Souterfell side, a place so extremely steep that a horse could scarcely travel upon it at all. The figures appeared to run at an amazing pace till they got out of sight at the lower end of the fell." On the following morning they went up the steep side of the mountain in the full expectation of finding the man dead; but no trace of either man or horse could be found, and they could not even discover upon the turf a single mark of a horse's hoof.

It is supposed to have been caused by refraction: the horses were somewhere near the mountain, and, by some peculiarity in the atmosphere, they appeared to be on the Souterfell.

Similar appearances have been noticed at sea; sailors have seen an image of ships in the air when no other ship than their own was in sight, and the images in the air were not reflections of their own



ship. Sometimes the ships were erect, and sometimes they were inverted, or two seen hull to hull. Suppose the invisible ship was at A and the spectator at B, the images were seen somewhat as at C and D. These

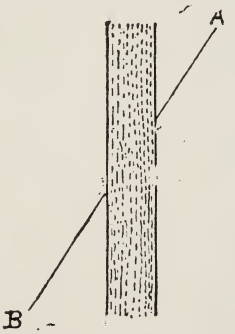
aërial visions are owing to refraction, when a suitable condition of the atmosphere exists.

This reminds one that it is said in scripture that at the revelation of the Lord Jesus to this earth "*every eye* shall see him." Have you ever thought of this? A sceptic may ask, How can this be, since people are scattered all over the round earth? How is it possible that they can all see the same person at the same time? Scripture does not exactly say that it will be at the same time, but why not? God explains that "as the lightning cometh out of the east, and shineth even unto the west; so shall also the coming of the Son of man be." (Matt. xxiv. 27.) Certainly all will see Him, for God has said it, though we know not *how* it will be brought about. And the wonderful things seen at times in nature—thought to be impossibilities—should surely teach even a sceptic to hold his peace. With God nothing is impossible, He who gave laws to nature, can surely alter them as it pleaseth Him, and work out all His purposes. Yes, *every eye* shall see Him; *every knee* shall bow to Him; and *every tongue* shall confess that Jesus Christ is Lord. What a mercy to bow to Him now and own Him Lord: such will be rejoiced to see Him.

EVENING IV.

OPTICAL ILLUSIONS, THE RADIOMETER, SOURCES OF LIGHT, MEASURING ARTIFICIAL LIGHT, TWILIGHT, ETC.

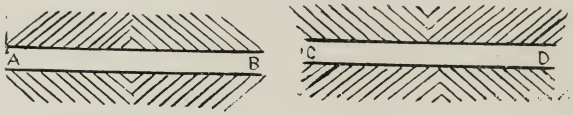
THINGS do not all appear as they actually are. We have already seen an instance of this in a straight lead pencil appearing bent by refraction, and also when things are rapidly whirled round what a changed appearance they have. These are, however, satisfactorily accounted for ; but there are other things that are not as easily explained. For instance, if a straight narrow line (A, B) runs across a wide line, the narrow line on one side will not appear to be in a line with the other side ; but



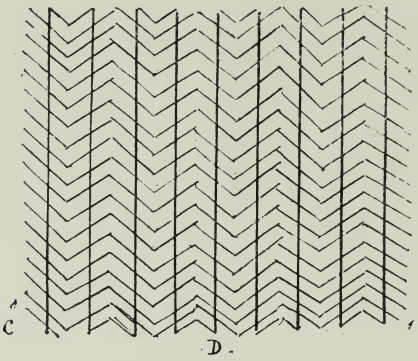
if the sheet is held up, and the eye directed *along* the line from B to A, it will be seen to be quite straight, or it can be tried by a rule or straight edge.

Take another illusion. Here the long lines seem to

approach nearer to each other at the centre than at A and B, though they are parallel. When the short



lines lean the reverse way, as C, D, the long lines appear wider at the centre.



In this illustration the upright parallel lines appear to lean right or left according to the way the short lines are drawn that cross them. If the page is held sideways, and the diagram is looked at from C, the illusion will be the greater, and the appearance seem extraordinary. But on holding up the page and presenting D to the eye, the illusion vanishes at once. It is plain therefore that it is the cross lines that cause the singular appearance.

It has been recorded that in some of the fresco painting discovered at Pompeii, lines have been

found which were painted *out* of the parallel, because of other lines near them, which would have made them appear incorrect if drawn parallel. Neglect of this elsewhere has had a bad effect. The above illusions have not been satisfactorily explained.

There are circles called "Strobic circles," which are sometimes seen in advertisements. Several circles are drawn within one another, forming a series of black and white or any colour and white. If these are moved with a circular motion before the eyes, they will appear to revolve afterwards of themselves for a short time. It is as though the rotating them left impressions on the retina which are not removed when the actual motion ceases.

Another curious illusion is caused by rolling up a sheet of paper into a tube. If this is held before one of the eyes, and a hand placed at a little distance from the other eye, a round hole will appear in the hand, and we seem to see things *through* it. This shews that what is seen by *both* eyes is made into *one* picture in the brain.

THE GAZING PORTRAIT is another illusion. It has often been noticed that when a portrait is drawn full face, or nearly so, the person portrayed appears to look at a spectator whether he stands opposite to it or not. The eyes in the picture seem to follow the spectator as he moves either to the right or to the left. If the portrait is drawn with a side face this strange effect is lost. You may be curious, as many others have been, to account for the former phenomenon. It will help to explain it by looking at a bust instead

of a portrait. The eyes of the bust seem to look at us if we stand opposite to it, but if we move on one side, the eyes do not seem to follow us, because we see only a *side* of the eyes, of the nose, and of the face, and this is not at all the same as when we stood opposite to it. With the portrait it is quite different: when we move to one side we see it exactly the same as when we were opposite to it—a full face: the nose, eyes, and face appear exactly the same; it is as if the picture had turned to face us. And this gives the curious appearance of its eyes following the spectator.

THE RADIOMETER.*

This is a very delicate instrument, made as light as possible. It has four small arms of glass with very light discs at the ends, pointing to the four quarters of the horizon. They are mounted on a pivot at the centre, so that they can revolve, and this with as little friction as possible. All is enclosed in a glass globe, exhausted of air. One side of each disc is coloured black, and the other left white, and they are arranged so that you can see two of the black sides and two of the white. On a light being brought near, it begins to revolve. The radiometer may sometimes be seen in an optician's window, revolving by the light of the sun, with more or less rapidity, according to the brightness of the light.

It is not easy to account for this motion, for the

* A measurer of radiation: from *radio*, to emit rays, and *meter*, a measure.

light falls with no greater force upon the black sides than upon the white sides, yet they spin round as long as they are exposed to the light. The supposition by some is that it is not the light that turns the discs, but the heat that accompanies the light. Though the air is exhausted from the globe there is still a little left, and the black sides of the vanes absorb more heat than the white sides, and this heats the rarefied air and causes it to move, and that moves the discs. This does not seem a very satisfactory explanation, for, though warm air rises, why should it move away from the light?* The dark side turns *from* the light, and in doing this brings another dark side towards the light, and thus the rotation is continued.

SOURCES OF LIGHT.

It need scarcely be repeated that the sun is the great source of light furnished to this earth. Light comes to us direct from the orb itself, and it comes also reflected from the moon and the planets. It is to be remarked that scripture shews that light existed before the sun is named. This has been supposed to be an error, as if the sun was the source of *all* light. But, as far as we know, the stars, in distinction from the planets, have light in themselves, and we can also easily conceive of there having been light before that of the sun, perhaps connected with the beautiful nebulæ seen in the heavens, which also give us light.

* It is supposed by others that "light has a repulsive effect in a vacuum, but attractive in air of ordinary density."

ELECTRIC LIGHT. This we see in the heavens, in the lightning, which at times lights up the whole atmosphere. It is the spark of an electric discharge on a large scale. Electricity can be produced by man, and is now being applied in a variety of useful ways. For lighting purposes two plans are adopted, with sundry variations. In one, called the *arc* lamp, a sort of constant spark is produced, and made to pass between two pencils of carbon, which are consumed by the electricity. The other is an *incandescent* light by a small glowing wire, or rod, in a vacuum. Both systems require a *large amount* of electricity, too much to be produced with economy by means of batteries. Either a steam or gas engine is generally employed to work a machine, called a dynamo, which produces the electricity.

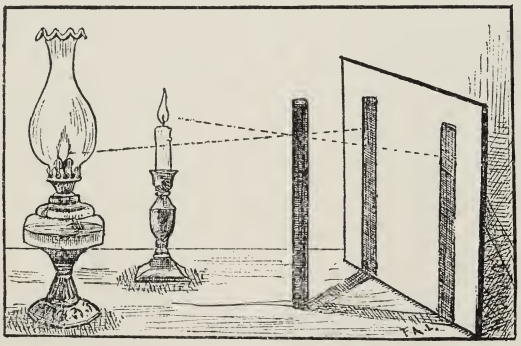
PHOSPHORESCENCE is a term applied to the comparatively faint light emitted by various bodies, unaccompanied by sensible heat ; but the term is by no means confined to the light shewn by phosphorus. When common lucifer matches are used in the dark, a streak of light may often be seen where the match is struck. This is caused by the phosphorus in the match. Various mineral substances also exhibit a faint light : as the sulphide of calcium, from which luminous paints have been made. Some shew a light when heated. Light may often be seen at sea on the crest of the waves, caused by numberless minute marine insects. Light may be seen at times in decaying bodies. A cook has been surprised on going to a larder to fetch a fish, to find it shining. Then there

are glowworms and the great Lantern or Fire Fly, the Sea-pen, &c., which emit light in the dark.

COMBUSTION. This has been described as 'the union of an inflammable substance with oxygen, by which light and often heat is emitted:' as gas, oil and spirit lamps, candles, fires, &c.

MEASURING ARTIFICIAL LIGHT.

We often hear of certain lamps giving the light of so many candles, or a small electric light may be said to be equal to twenty candles. It is interesting to know how light can be measured so as to make or test these statements. It is done by means of shadows. A sperm candle is taken as a standard. Any one can test a lamp in the following



simple manner. Pin up a sheet of white paper to a common wooden box at one end of a long table, then a little way from this stand up a round ruler. Place the lamp at the farther end of the table, and notice the shadow of the ruler on the paper. Now

put the candle between the lamp and the ruler, but a little on one side. This will throw a second shadow on to the paper. Notice if one is darker than the other (not forgetting that the shadows will cross each other), and move the candle until both shadows are of the same depth of darkness. Now measure the distance of the candle and of the lamp from the screen. Suppose one is five feet and the other ten feet ; square both the numbers, one is 25 and the other is a 100. The proportion of these numbers is 1 to 4, and the lamp would be said to be equal to four candles.

TWILIGHT, ETC.

Twilight is caused by the sun (before it has risen or after it has set) shining upon the upper part of the atmosphere, and the light being broken up, as it were, into minute waves produces that beautiful soft light, seen before the sun rises and after it is set. The red glow seen at times in the twilight is caused by a particular state of the atmosphere. In the morning, as referred to in scripture, it foretells rain : the watery vapours reflect the red rays. In the evening, a similar colour may be produced by high cirrus* clouds, and be followed by fine weather.

HALOS are occasionally seen as large rays of light round the moon and sun, which sometimes appear as circles of cloud. These are supposed to be caused by minute crystals of ice, high in the atmosphere, which refract the light so that it is visible to us in the shape of a large circle.

* Literally 'a tuft of hair, curl :' high clouds in the form of curls.

THE AURORA BOREALIS* is a beautiful arc of light, seen in the heavens by those living in the north. The colours are ever varying, and are more or less brilliant. They seem to come from various parts of the heaven, but converge to a point toward the north. It appears after the close of twilight, gradually brightens, and at length fades away.

It is pretty generally agreed that the aurora is connected with electricity, which is produced in the atmosphere. Experiments have been tried by passing electric sparks through various gases, to endeavour to produce colours similar to the aurora. It is found that if a spark is sent through a vacuum with a small quantity of gas in it, beautiful effects are the result. The air gives a fiery red to a violet colour; nitrogen gives orange-yellow; and carbonic acid, a green. Thus in the component parts of the atmosphere there are all the materials needed to produce the beautiful colours seen in the Aurora Borealis.

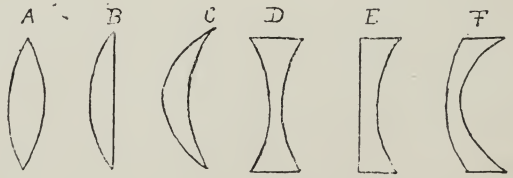
Thus God has been pleased to give the inhabitants of the dreary regions, far north and south, who, for months together, do not see the sun, these beautiful exhibitions of light and colour.

* It signifies 'the northern aurora,' or northern light, though 'aurora' signifies 'morning.' There is also the Aurora Australis in the southern hemisphere.

EVENING V.

LENSES, THE MICROSCOPE, THE TELESCOPE.

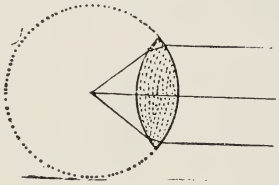
IF we look at things through a magnifying glass they appear larger. It is the same with a microscope, for with this instrument many things invisible to the naked eye are plainly seen. On the other hand, a telescope is used to shew things at a distance. Things that are invisible because of the distance, are seen by means of this instrument, and things indistinctly visible are seen more plainly. We have already spoken of different sorts of spectacles; but we must look a little into the principle on which the various lenses are formed. It may seem to be a dry and difficult subject; but its study will bring out some of the wonders of creation.



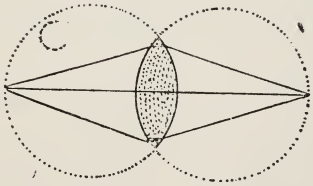
These are the principal lenses. The point where the varying rays that pass through a lens meet is called the *focus*, and the distance of the lens from the focus is called the *focal length* of the lens. The thicker a lens is in comparison with its size the shorter is its focal length. We have seen that the

denser the medium the greater is the refraction, and that it varies also in different sorts of glass for the same size lens. We will suppose the lenses are made of crown glass, which allows the focus to be illustrated by the centre or circumference of the circle corresponding to the curvature of the lens.

A is a double convex* lens: parallel rays will meet at the centre, which is its focus; and a light placed in the centre will send out parallel rays.

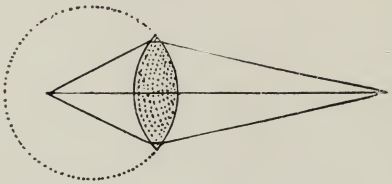


If the light be removed to the circumference the focus will be at the same distance as the light.

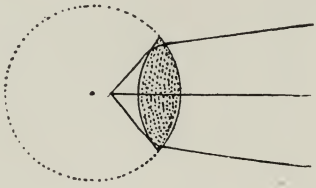


* 'Convex' is from the Latin *con*, together, and *veho*, to carry, 'to carry together, brought round.' 'Concave' is from *con*, intensive, and *cavus*, hollow, like a cave, 'completely hollow.' If it is noticed that the hollow lens is like a *cave*, the two names will be easily remembered.

If the light be moved from the circumference nearer toward the centre the focus will be farther off.

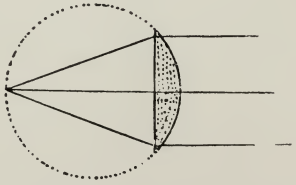


If the light be put closer to the lens than its focus, the rays will be divergent, or spreading.



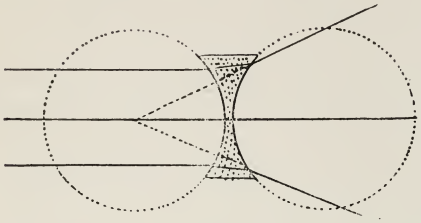
The above will suffice to illustrate a double convex lens.

B is a plano-convex lens, and parallel rays will meet at the circumference (instead of at the centre, as

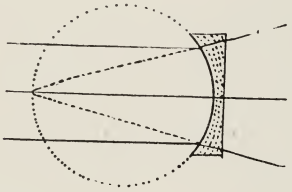


in A); and conversely a light at the circumference (which is its focus) will emit parallel rays through this lens.

D is a double concave lens. Parallel rays are divergent as if coming from the centre.



E is a plano-concave lens. Parallel rays are also divergent, but the focus is at the circumference.



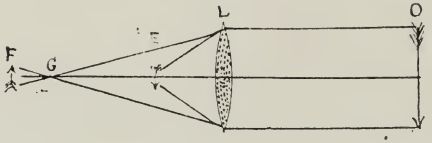
C and F are both concave-convex lenses: but in C the convex is the smaller circle and has the greater power, and the glass acts as a convex lens, and the rays are convergent (meet together).* In F it is the reverse, the concave has the smaller circle and the greater power, and the glass acts as a concave lens, and the rays are divergent, or spreading.

It will be seen that A, B, C are thicker in the centre than at the edge, and the rays are convergent: D, E, F are thicker at the edges than in the centre, and the rays are divergent.

* C is also called a *meniscus*, a Greek word, signifying 'a little moon'

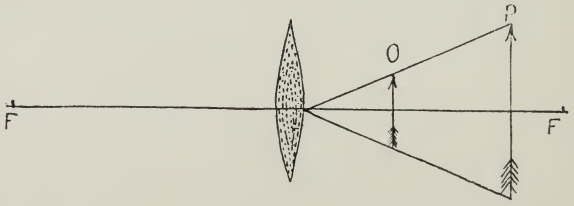
As in C and F both sides of the lens are not of the same curvature, so in the double convex one side can be made with a larger curvature than the other, as indeed is the case in the crystalline lens of the eye.

We must next see how things are viewed through the double convex lens. It may be explained thus.



If we take a reading glass, which is a double convex lens (L), and place it near the eye, we can see a distant tree *erect*, (as the arrow (D) would be seen at E); but if we hold the glass at arm's length, the same tree will appear *inverted*, as at F, because the rays have crossed at the focus of the lens at G.

An object at O, nearer to the lens than the



focus, will appear as an enlarged image at P. F represents the focus of the lens.

In the double concave lens it is just the reverse of this. An object at P will appear as a smaller image

at O. Such lenses are used by short-sighted people, in whom the crystalline lens is too convex, and enables them to see things clearly at the usual distance from the eyes.

In long or weak sight, the focus falls beyond the retina; in short sight it does not reach the retina: the lenses already named rectify both these faults.

We have often spoken of all the rays meeting at one point, called the focus of a lens; but they do not all exactly meet at one point: the rays that pass through the marginal portion of the lens meet nearer on the central line (called the *axis* of the lens) than do the rays nearer the centre. This is called SPHERICAL ABERRATION, that is, wandering or differing, because of the sphere or shape of the lens. In telescopes and microscopes this can be corrected by a stop, called a *diaphragm* (a round disc with a hole in the centre), which stops some of the rays, and renders the image more distinct. But this shuts out light, and therefore the optician seeks to combine different shaped lenses so as to correct this aberration.

There is also another difficulty the optician has to contend with. It is called the CHROMATIC ABERRATION. When we come to speak of the colours of the rainbow, we shall find that a pencil* of white light is a combination of coloured rays, and these rays have different refrangibility; that is, they are re-

* A 'pencil' of light is a term often used to express a number of rays; we can hardly say that a ray of white light is composed of a number of rays.

fracted at different angles, so that they are not all brought to the same focus. The diaphragm stops some of the colours, but this does not remove the error. Opticians in a great measure remedy the defect by combining lenses of different glass, such as flint and crown glass. A telescope or microscope with such corrections is called *achromatic*, meaning, as we have seen, without colour.

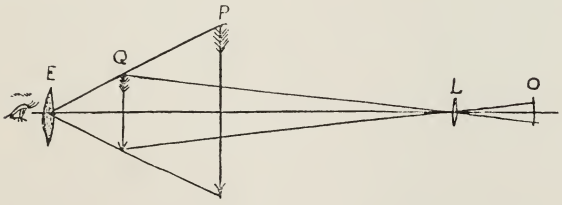
Now, do not all these considerations shew us what a wonderful instrument the human eye is? No aberration appears either as to its focus or respecting colour. It sees all things clearly, and, in a sense, measures their actual size, notwithstanding their distance; and the colours in nature are not confused, nor do any appear when there is no colour. The eye is the work of the infinite Creator, and is, we again declare—*perfect.*

Some of the animals and insects have eyes in some respects more wonderful than our own. They have thousands of lenses, and can see as well behind as before them, and in every direction. Thus the common house-fly has two thousand lenses in each eye, and each lens is a double convex. Think for a moment how small the complete eye of a fly is, and then try and imagine how each can contain two thousand perfect lenses! And the eyes of some insects have even many more lenses than the house-fly. Who but the Almighty God could have formed such eyes as these, or, indeed, such eyes as our own?

THE MICROSCOPE.*

The microscope in its simplest form is a double convex lens only. Such glasses are often conveniently mounted so as to be carried in the pocket, or they can be put into a short tube made of horn, such as are used by watchmakers; but when lenses are intended specially for microscopes they are made of various shapes, such as a double convex, with one side of the lens more convex than the other.

The microscope is called 'compound' when it has more than one lens. Thus, let us suppose it has two lenses as shewn here. O is the object; L is the lens nearest to the object, and is called the object glass or the objective; and E is the eyeglass. An enlarged image of the object is formed, by the object glass, at Q. This is again magnified by the eye-glass, and is seen at P.



To judge of the magnifying power of such a microscope, the power of the two lenses has to be multiplied. Thus, if from the object to Q be ten times the distance from the object to L, the power of L may be

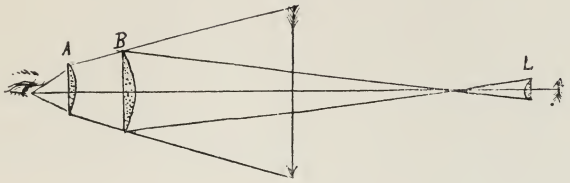
* From the Greek *mikros*, little, and *skopeo*, to see.

said to be 10; and if the eyeglass has a focal length of 1 inch, and the distance of the most distinct vision be 10 inches, the power of the eye-glass is 10; and 10 multiplied by 10 is 100. This means that a line, the 100th part of an inch, would be magnified into an inch. But suppose the object examined were a square, measuring the 100th part of an inch each side, this would be magnified both in depth and length, and be a square inch. Thus the object may be said to be multiplied 10,000 times, because it is 100 times each way. Persons are often disappointed after purchasing a microscope. They may be told it magnifies 10,000 times, and they find that a line is magnified only 100 times. The above will explain what is meant.

Microscopes are generally supplied with two or three different object-pieces (the part that carries the object glass), because sometimes the owner may wish to examine the *whole* of a small insect, and then he would need a low power; but at other times he may wish to examine some minute *part* only of the same insect, and then he would change the glass for a higher power. The powers are often marked by the distance the object has to be from the object glass; as an inch, half-inch, quarter-inch, etc., the first being the lowest of the powers named, and magnifying the least. An inch and a quarter-inch are good working powers. Some instruments have also two or three eye-pieces, known as Nos. 1, 2, &c., which also increase the power.

The better class of instruments has an eye-piece different from the above, called the *Huyghenian* eye-

piece (named after the inventor, Huyghens, a Dutch astronomer) and the whole would be arranged thus :



The eye-piece has two plano-convex lenses, A, B, the larger of which is called the field-glass. A diaphragm or stop is placed between them to cut off some of the rays. This arrangement if properly carried out corrects both the spherical and the chromatic aberrations, already spoken of.

Some microscopes are made with two tubes, with lenses for both eyes : they are called double or binocular ; but such are not much used.

It is only minute objects or *parts* of objects that are viewed in microscopes. In a good light you can see *through* many objects. In a tadpole, for instance, you can see the blood circulating in his veins ; and the inside of other insects can be seen. Also the various parts of their limbs.

The leaves of flowers and plants are most beautiful, shewing magnificent colours and perfect structure and pattern.

Quantities of minute shells, and lovely little pieces of coral, may be seen in a speck of sand so small that we should think it almost nothing.

Diatoms also, though mere specks, shew the most

perfect patterns of what may be perhaps called filigree-work.

There is also another use to which the microscope is put, namely, to discover the deceptions of man. There are many articles of food that are adulterated by dishonest men, in order to obtain larger profits than they could get honestly. Well, the microscope exposes many of these adulterations, and thus the dishonesty is discovered.

The microscope also shews the contaminations in water. Very little of it is quite pure, though its accompaniments may sometimes be harmless. Water out of a pond is often found to be full of animalcula (that is, minute living creatures much too small to be seen with the naked eye) and other impurities. Water should be always boiled or filtered before being drunk.

Scarcely anything shews the superiority of the handiwork of God over the works of man like the microscope, as we have already named. Some artificial flowers are made to look very like real ones; but place a leaf of the former under a microscope and it is a mere daub of paint, &c., whereas every leaf of the real flower is full of beauties. Indeed, everything that God has made is not only perfect but beautiful, and the stronger the powers of the microscope the more the beauties are seen; but the finest work of man is the very reverse: the more it is examined, the coarser it appears.

There are many appliances made to the microscope, such as various stages on which to place the objects,

whether alive or dead, or in which to place liquids ; also contrivances to throw the light on to the object, or through the object ; rackwork to move the glasses nearer to or farther from the object, the best instruments having two arrangements for coarse and fine adjustments, so as to put the instrument and the object in exact focus ; a diaphragm under the stage to shut out the light where it is not wanted ; some have a Finder, for use when very high powers are employed ; a Camera Lucida by which to sketch any object that may be under review ; a Polariscope for shewing the polarisation of light (which will be explained another evening) ; and a piece of ruled glass is also added, by which the *size* of an object may be measured to the thousandth part of an inch.

The microscope reveals some of the most marvellous things in creation, not only, as we have said, shewing the beauty of everything, but revealing the countless animalcula which are invisible to the naked eye, which yet have limbs and joints and internal organisms suited to the mission they have to fulfil. So we value this useful instrument, because by its means we discover more and more of the wonderfully minute works of our Creator-God.

THE TELESCOPE.*

Both in the microscope and in the telescope the lens nearest the object is sometimes called 'the objective,' and the lens nearest the eye is called 'the eye-piece.' In the microscope the smaller glass

* From *tele*, at a distance, and *skopeo*, to see.

is near the object, and the larger one near the eye; it is the reverse in the telescope, the larger being the objective.

The simplest telescope is the Astronomical. It has only two lenses; but then it inverts the objects. This does not signify in viewing the heavenly bodies; but it would be awkward for a marine or field telescope to shew everything upside down, so other glasses are added which again reverse the image, so that it is seen in its true attitude.

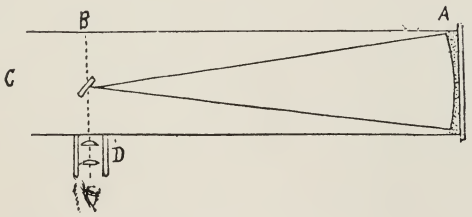
When I say that an astronomical telescope has but two lenses, I mean two *compound* lenses already spoken of. Such are called Achromatic telescopes: that is, as I have said, the lenses are made of two or three pieces of different sorts of glass, such as that called flint glass and crown glass, so that any little colour that either glass might shew is corrected by the other. The lenses are made thus in order that the telescope may shew no colour but what is in the object itself. This is important also for an astronomical telescope, because some of the stars are coloured, and are thus distinguished.

The arrangement of the lenses for a telescope is similar to that for a microscope. In the latter the object glass is very small, and of course its focus is very different in the two instruments. A Huyghenian eye-piece is used in both instruments.

For terrestrial objects the eye-glass of some astronomical telescopes can be removed, and a larger arm screwed into its place, which contains other glasses properly arranged. There are thus four lenses

in a common telescope, and when they are jointed to shut up into a small compass, the two glasses nearest the eye are generally in the last piece of tubing, and need pushing in or out to suit the distance of the object or the eye that is looking at it. In some of the old telescopes that are made to shut up very short, the two lenses nearest the eye end are in *two* different pieces of tubes, and people have been sadly puzzled as to why shifting the *last* piece did not bring the things seen into focus. In such telescopes the last piece but one should be shifted, and the right focus would be obtained.

There is another form of telescope, which was used by Sir Isaac Newton, and which has latterly come into use again. It is a *reflecting* instead of a *refracting* instrument, as the ordinary telescope is called.



A is a thick piece of glass, concave on one side, which is covered with a coat of silver. It is called a *speculum.* The rays enter at C, and are carried to the speculum, and from thence they are reflected and meet in a focus at B. A small mirror hung there on thin supports receives the image, and reflects it to the eye-piece at D. The small mirror

at B and its supports do not obstruct the rays passing down the tube to A.

Such a telescope gives good results, and is very convenient when the object is high up in the heavens, because it requires no stooping, as is the case with the common form. Earl Rosse had a reflector made, with an aperture of six feet, and a focus of fifty-three feet; quite an elaborate structure was needed for its use.

In some of the smaller reflecting telescopes the speculum, instead of being silvered glass, is made of solid silver, and needs then only keeping bright. The glass ones need from time to time to be re-silvered.

Many large telescopes are mounted on heavy stands, and in such a way that a person can sit on a stool, and with the end of a stick in his hand, by which to turn the instrument, can keep the same star in the field of view for hours together. If you ever watched a star, you would see that it rises from the east, and, like the sun, gets to its highest in the south of the heavens, and then begins to descend. A telescope in order to keep such a star in view must be made to move in a line with the equator, and then be shifted higher or lower as the star is above or below the equator of the heavens. A telescope mounted thus is called an EQUATORIAL.

Some telescopes have clock-work attached, and this keeps them moving just at the right speed to keep an object in the field of view. For instance, if a person wanted to view the changes that take place in the

appearance of some of the stars, he would set the telescope in the right direction, and if called away, the clock-work would keep the telescope moving, and when he came back he would find the same star was still to be seen.

In large telescopes there is always a small one by its side, called a *Finder*. This is used to find the star you want, for though you may be able to see the star with the naked eye, it is often very difficult to get the telescope exactly in the right position so as see it. It is found therefore first in the Finder (with which you can get a view of a much larger space in the heavens, because it does not magnify so much), and if the telescope is moved till the star is in the centre of the Finder, it is then to be seen also in the large telescope.

Persons with telescopes equatorially mounted often want to *look for* stars which cannot be seen with the naked eye. The heavens are mapped out and described by 'right ascension' and 'declination,' in a manner similar to the divisions of the earth into longitude and latitude. Many lists of the principal stars are published, and by turning the telescope to the place indicated (corresponding scales being attached to the instrument), any particular star can be found.

There are other appliances that can be added to the telescope. Thus the heavenly bodies can be photographed, and the relative position of the stars, the mountains in the moon, &c., can be depicted with wonderful distinctness. The spectroscope is another

useful accompaniment to the telescope, as we shall see.

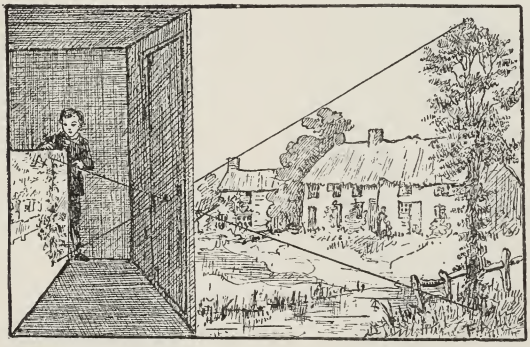
Short telescopes with glasses for both eyes, called BINOCULARS, are often used by hunters and in the army and navy, because they can be held so much more steadily than the long telescopes. They have a double convex for the object glass and a double concave for the eye lens.

The telescope has revealed many of the wonders of the universe. It has shewn us how very similar the planets are to the earth we inhabit. They have day and night the same as we have, and they have moons revolving round them like our moon revolves round the earth. It also shews us how *little* the earth is in comparison to other planets, and how *near* we are to the sun (though we are nearly 92,000,000 miles off) in comparison to many of the stars. It shews also the wonderful surface of the moon, with its mountains and its awful chasms. Surely the heavens declare the glory of God, and the firmament sheweth His handiwork!

EVENING VI.

THE CAMERA OBSCURA, CAMERA LUCIDA, OPTICAL LANTERN, STEREOSCOPE, KALEIDOSCOPE.

THE name Camera Obscura simply signifies 'a dark chamber.' If a hole is bored in the shutters of a dark room and a double convex lens applied to the hole, some of the exterior persons or things will be reflected on a sheet of paper. If the

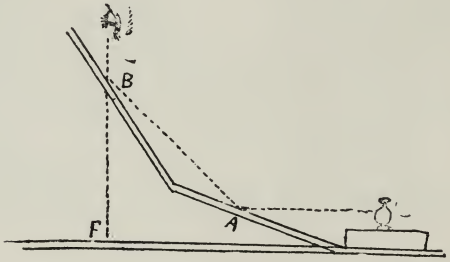


lens is fixed to one end of a box and a mirror is placed at an angle, the images may be thrown upward on to the ceiling or downward on to a table. Or the box may be placed in the roof of a temporary room, and the images be thrown on to a white table. We are not aware that this has been turned to any useful purpose. Such are erected at some seaside places to amuse the visitors.

THE CAMERA LUCIDA.

This is 'the light chamber,' and is utilised for copying objects. Its name is very inappropriate, for it has no chamber at all. Things can be copied simply by holding a piece of glass at an angle of 54° * with the horizon on a sheet of paper on the table. If a coin, for instance, is raised vertically above the table facing the glass (with the glass leaning from the coin) its reflection will be seen by looking *through* the glass, and it can be copied with a pencil, but the image will be reversed. The light must shine on the coin, but the other side of the glass, where the copy is to be made, should be shaded.

By letting the light from an object fall upon a



looking-glass, at an angle of 22½ degrees with the horizon, and then having a piece of plain glass elevated at an equal angle with the vertical, the object will appear *direct*, and can be copied as before. The image will be seen on a piece of paper at F, if the eye is placed as represented.

* See page 30.

In some of the instruments made for sale, the above angles of the looking-glass and the sheet of glass are preserved in one solid piece of glass; a lens is also added to make the pencil and the pictures more distinct, a plate with a small hole in it keeps the eye in one position.

If an object is much too distant to be copied thus, a small telescope can be used, and the object be copied by the camera lucida.

On the other hand, if an object is much too small to be copied, a camera lucida can be attached to a microscope. The microscope is turned horizontally, and by looking through the camera the object enlarged will be seen on sheet of paper, and can be copied.

Even a simple, clean piece of glass can be used for the purpose of copying. Fix the glass vertically just before you; place the copy horizontally at your left hand, towards the light and close to the glass; look *through* the glass on to a sheet of paper placed

on the other side, and the object can be copied, but it will be reversed.

Now-a-days, when there are so many illustrated books, and often but little time allowed for engraving the wood-cuts, we can easily understand that, where photography is not available, the camera lucida is an instrument of great utility, combining speed with accuracy.

THE OPTICAL LANTERN

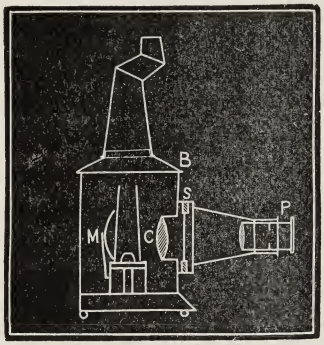
This is often called the Magic Lantern, but it is unfortunate that the word 'magic' should ever have been attached to this contrivance, for there is nothing about it connected with magic. The lantern was first used more as a toy, and then, to excite wonder, the objects in the slides were made to move, which may have seemed mysterious, and thus have gained for it the foolish name of 'magic.'

Though formerly used simply to *amuse*, it has now for years been used to *instruct*. A whole class, or, indeed, a room full of people can be shewn an enlarged image of anything that needs to be examined or explained in detail.

The lantern is simple in construction. It consists of a light, and a condenser to condense the light on to the transparent picture. The light goes *through* the picture on to a lens, which brings the picture into focus and throws it on to a screen or white sheet on the wall.

We will look at a lantern in its simplest form.

M is a reflector placed behind the lamp, to throw the light through the condensing lens C, which here is double convex. S is the place where the picture (called the *slide*, because it slides in or out) is placed. The



lens to focus the picture on to the screen, is in a moveable piece at P, which can be drawn in and out as required. It is called the objective. By what we have already observed as to a double convex lens inverting a picture, it will be seen that the slides must be placed in the lantern upside down.

Attached to some lanterns there is also another contrivance, which created much surprise some years ago, though now it is common enough. While one picture was being shewn, it seemed to *dissolve* into another picture, and thus they came to be called DISSOLVING VIEWS. This is generally done by having two lanterns, with a picture in each. While one is on view, the other is shut off. When one has been exhibited long enough it is partially covered, and the other is partially opened, the one being slowly closed,

and the other opened, till the new one is fully exposed and the old one entirely covered. No doubt it can be done with one lantern (if the place S is wide enough to hold two slides) by shading the picture and slipping in another behind it.

When the lantern began to be used for teaching, efforts were soon made to improve it. One principal improvement is in the light. Lamps were made with two and three wicks, which gave a much greater light. The common gas was used with an argand burner. An oil lamp called the sciopticon was invented, which has three wicks, and requires no glass chimney. Its light is said to be superior to the argand gas light. The best light for large halls is the oxy-hydrogen, or lime light, but it is somewhat troublesome to use. The oxygen is generally put into a thick bag of india-rubber cloth, on which weights are placed to gradually force it out, but it can also be condensed into an iron pipe or bottle. The hydrogen is the common coal gas. Two pipes meet at a point, and the light of the combined gases is made to fall on to a piece of lime or chalk: hence the name Lime-light. Some use two plano-convex lenses for the objective, placing the plane parts of both facing the picture; and some have two lenses for the condenser.

There is also an arrangement of *three* lanterns combined, but the principal use of it is to give effect by introducing storms, lightning, avalanches, or even earthquakes. For simple instruction, a good single lantern is all that is needed.

We have spoken of the pictures being transparent

and the light shining through them: but opaque objects can also be shewn by some lanterns. In one arrangement the object is placed at an angle to the condensers, and the reflector shifted till the object is well illuminated, and then the *reflection* of it is thrown through the object glass on to the screen.

Many of the principles of optics can be illustrated by the lantern, by using special arrangements for that purpose. Thus the spectrum can be examined, polarised light, &c. The microscope can also be used in combination with the lantern, and minute objects be exhibited and explained.

We thus see how the lantern is turned to the useful purpose of instruction. Young people often retain in the memory things that they have *seen* more than those they have merely read of in their lesson books.

THE STEREOSCOPE.*

This instrument may be seen in many houses. It is simply a small box, blackened inside, but having part of one side to lift up to admit the light. There is a division in the centre of the box, and a lens for each half at the top, and a place at the bottom for the slides. Anything correctly drawn on the slide, and properly seen, appears as standing erect.

In order to understand the principle of this instrument it is needful to consider how we see an object with both eyes. As early as A.D. 130–200 this was explained by Galen, a celebrated Greek physician. He says, "Standing near a column, and shutting each

* From the Greek *steros*, firm, solid, and *skopeo*, to see.

eye in succession, when the *right* eye is shut, some of those parts of the column which were previously seen on the *right* side of the column will not now be seen by the left eye; and when the *left* eye is shut, some of those parts which were formerly seen with the left eye on the *left* side of the column will not now be seen by the right eye. But when we, at the same time, open both eyes, both these parts will be seen."

The same thing can be tried by holding the left hand sideways a little distance off, opposite the nose. If the left eye is shut, the inside of the hand will be seen; if the right eye is shut, the back of the hand is seen. We shewed on page 23 that the same thing could be proved with two needles.

By this it is evident that both eyes do not convey to the retina exactly the same image; but the brain, as it were, combines the two images, and by experience we know that we are looking at only *one* object.

That experience teaches as to this is proved by a person whose sight is recovered by couching: he cannot at first tell the form of an object that he sees (though he may see it perfectly with both eyes) until he has learned by experience the difference that various forms present.

It has been noticed that a man with only one eye cannot judge readily the form of any object he has not seen before. He moves his head unconsciously from side to side to see it as others do with two eyes.

The distance of an object is also learned by experience. A baby will often grasp at a thing beyond its reach. We judge of distance by the angles of

vision under which each eye views anything, as well as by the things that are nearer to us.

The chameleon gives a remarkable illustration on this point. Its eyes are set in projecting balls which turn freely in their sockets. When we look at an object we turn both eyes at once in the same direction ; but the eyes of this animal are independent one of the other, so that with one eye he may be watching a fly, while with the other he is searching in another direction ; but as soon as he judges that a prey is to be caught, he fixes both eyes upon it, and that enables him to judge of the distance, and as soon as within reach, his long tongue seizes it. He does not trust to one eye for this.

Now if a flat picture is to appear in the stereoscope as solid, or as raised, it must be drawn twice, and drawn exactly as each eye would see it. This was shewn by Professor Wheatstone long since, but the difficulty was to get the objects drawn accurately enough. No artist seemed able to produce them sufficiently exact, except a few geometrical forms. Photography, however, has overcome the difficulty. By copying the same object with two instruments placed at a proper distance from each other (say $2\frac{1}{2}$ inches) the two needed views are obtained. Trees, buildings, &c., appear as standing out.

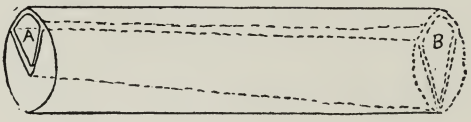
The above theory is confirmed by the fact that some persons, whose eyes differ, cannot see the two pictures in the stereoscope as one. They are in the habit of adjusting their sight in some way, and views taken for ordinary eyes do not suit them.

THE KALEIDOSCOPE.

This instrument was invented by Sir David Brewster, and he called it: "I-see-a-beautiful-form."*

Imperfect instruments may often be bought at the toy-shops; but when produced on scientific principles the effects are much more beautiful, and have been utilised in forming some of the best patterns used for carpet-weaving and other things.

Sir David Brewster intended to take out a patent for this instrument; but before he was able to secure it, the opticians heard of it, and made some and sold them as fast as they could be made. It was reckoned that 200,000 were sold in a few weeks. This was not honest, and was not obeying the golden rule, "to do to others as you would wish them to do to you."



The proper construction of the instrument is shewn in the figure: two pieces of glass run from A to B, being wider at B than at A, and joining nicely where they meet at the bottom. The backs of them must either be silvered or blackened, and the top of the case between the pieces of glass must be blackened *dead*, that is, without shining; or be lined with black velvet. The case may be made of cardboard.

* From the Greek *kalos*, beautiful, *eidos*, a form, and *skopeo*, to see.

The end A should be closed, and a small hole made in the centre. The case should be longer than the pieces of glass, and a circular piece of glass be put at B; a little space left, and on the outside a piece of ground glass fastened to a cap that can be taken off.

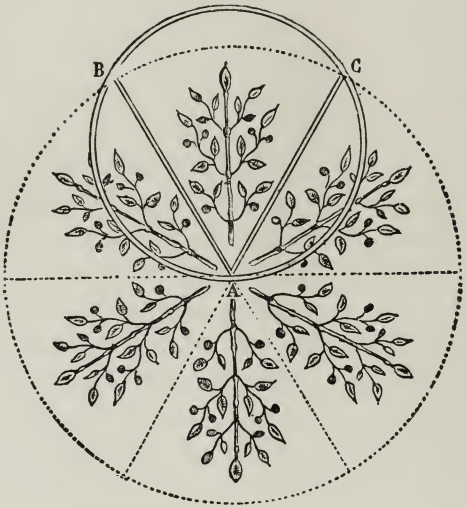
In the space left at the end of the case, anything can be placed to be viewed. The toys made for sale have small pieces of coloured glass, which make thousands of coloured patterns by turning the kaleidoscope round gently, the pieces of glass falling into different patterns as it is turned. Other things can be used to form the patterns, as needles, small twigs, pieces of seaweed, looped figures, squares, triangles, circles, angles. Too much must not be put in at a time, or there will not be room for them to change their position freely when the case is turned.

The kaleidoscope can be used in another way by taking away the ground glass, then any fixed object or figure, if well illuminated, can be seen multiplied in many various ways.

We have seen, on a former occasion, that every circle is supposed to be divided into 360 degrees, and one secret of a perfect kaleidoscope is, that the angle formed by the two glasses must be some aliquot part of the 360°. If the angle is a little too large, the image is deficient, and in some parts irregular and non-symmetrical; if the angle is a little too small, the image is redundant from a reduplication of one part.

The things viewed are reflected from each glass to the other and back again, the figure being multiplied according to the angle at which the glasses are placed.

This is an illustration when the angle is 60°. The figure will be seen in six aspects as here represented: A B and A C are the glasses, and the circle A B C shews the case.



The angle may be different from this, and may shew eight images, but more than eight will not give light enough.

From this it will be seen that if a single object is viewed, it will appear in several different positions. The effect produced, in many instances, is very beautiful, and makes the name given to the instrument appropriate—kaleidoscope.

EVENING VII.

PHOTOGRAPHY.*

WE have already seen that by the camera obscura the representation of natural objects could be thrown on to a white sheet; but they were not painted there; an object passed, and the picture of it was lost, perhaps for ever. The difficulty was, how to seize the picture and to fix it on to something, so that, when the object had passed away, the picture might remain, printed by the light itself. It is true that if the lenses were not good, or not of the proper shape, there might be slight imperfections in figure; but, on the whole, the pictures were true to nature, and shewed the things as they actually existed, without either favour on the one hand or what was false on the other. Thus the great desideratum was to bind and fix the picture, so that time should not erase or even dull it.

Then the next thing was to find some way of multiplying copies of the picture when one was fixed. Both these objects were at length attained, but we can easily imagine how many experiments were tried before the most suitable way could be found to seize and hold the picture. It was by studying what chemically-prepared films would best meet all the requirements. Multiplying the copies is called printing.

* From the Greek *phos*, light, and *grapho*, to write, delineate, draw, and thus *drawing by light*.

We will now briefly describe the apparatus and solutions necessary ; but different solutions would be preferred by some.

Perhaps every one is more or less acquainted with the outward appearance of the photographer's instrument. It may at times be seen in the streets, and especially at the sea-side in the summer, when visitors are solicited to have their photographs taken.

In appearance it is simply a small wooden box covered over with a black cloth, and supported on a slight stand with three legs. The more useful part is in the small box. Here there are lenses and lenses. They must be achromatic, and one of the pair of lenses must be moveable so as to get the right focus. It may be by one box sliding into another box, but this part is generally made like a square pair of bellows, which can be opened to the desired length, and shut up into a small compass when not in use. It is called a camera, which simply means a chamber.

For taking portraits, the compound lenses form a double convex, and a plano-convex, the plain part facing the double convex with a stop between them ; for landscapes the plano-convex is turned round with its convex part facing the double convex, and the stop *outside* the lenses ; or a landscape can be taken by a portrait camera by removing the back pair of lenses, if the camera will open far enough.

At the back of the camera is a plate of ground glass on which the operator can see if the person or object is rightly placed and properly focussed.

There is also what is called a dark slide, which

holds the glass plate chemically prepared until all is ready. Then the shutter is removed, and the light prints the image on the prepared plate, which is again shut up in the dark slide to carry it to a dark room, or what answers that purpose. The dark cloth thrown over the camera is also for the purpose of keeping out the light.

There is what is called the Positive process, when a picture is wanted on one plate of glass only, without any copies being printed. There is also the Negative process, the picture on the glass plate being called the negative, from which many copies may be printed. The Negative process may be further divided into the Dry process and the Wet process.

We will suppose a portrait is to be taken by the Wet process. The first thing is a light room, but not too light. The professional photographer has various blinds, which he can arrange so that the due proportion of light may fall on the face, not so much from *above* the sitter as in front of him. Then he must sit in proper attitude: a three-quarter face is considered better than a full or side face. This being arranged, and the operator having moved and focussed his camera so as to get a sharp image of the sitter to his satisfaction, he gets the glass plate on which the negative is to be printed.

We must however see how the plate has been prepared. The operator takes a plate made perfectly clean, and pours upon it about one dram of collodion, moving the glass about so that the collodion shall cover every part of the plate, when the rest may run

back into the bottle. In about twenty seconds it is dipped into a bath filled with a solution of nitrate of silver,* taking care that there is no pause in the dipping. Here it remains about four minutes. From time to time it should be examined, and when the fluid ceases to run in streaks, and the film has a creamy look, it is right. It is now shut up in the dark slide and is ready for use. This part of the work may be prepared beforehand, ready for use at any time.

The operator now places the plate in the camera, and cautions the sitter not to move, not to look too serious, &c. He removes the shutter, and, in about nine seconds, the portrait is taken.

The plate is again shut up in the dark slide and carried to the dark room. The room, though called dark, is not really so ; but what is essential is, that no chemical or actinic rays† should enter the room. The blinds shutting out all the other light must be yellow, or yellow paper can be pasted over the windows, or a yellow lamp can be used which gives enough light to work by.

The next process is called DEVELOPING. The solution‡ is prepared beforehand, and is now poured on to the plate enough to cover it, and is made to spread all over, and is continued to be moved over it as long as the details of the picture continue to intensify. It

* Composed of recrystallized nitrate of silver, ½ ounce; distilled water, 7 ounces; collodion, 7 drops.

† Explained farther on.

‡ Proto-sulphate of iron, 75 grains; glacial acetic acid, 2 drams; alcohol, 2 drams; and distilled water, 5 ounces.

should look much over-exposed with very little clear glass. The solution is now washed off with plenty of water being poured gently on to the centre.

This seldom renders the portrait dense enough on the glass, and further developing is needed, called *Intensifying*. Two solutions have to be prepared. Cover the plate with solution No. 1,* and then pour it off into a glass in which have been placed four or five drops of No. 2.† Shake the glass to mix them, and again pour on to the plate, and again into the glass, and repeat till the plate is dense enough. Experience must guide as to this. If kept too long it will become foggy, and be spoiled. The room need no longer be kept dark.

The next process is called FIXING, though it might be called Clarifying. The fixing solution‡ is poured on and off until the iodide of silver, which gives a cream colour to the film, is all dissolved, and the parts of the plate which correspond to the dark parts appear quite clear. Then wash off with plenty of clean water, and lightly brush over with a camel hair pencil to remove any dust or films of silver. The plate is then warmed till it can be only comfortably held.

The next process is called VARNISHING. *Crystal* varnish is poured on to the plate, and made to flow slowly over it, so as to leave a thin film. The surplus

* Pyrogallic acid, 10 grains; citric acid, 20 grains; distilled water, 5 ounces, This solution will not keep good long.

† Recrystallized nitrate of silver, 40 grains; distilled water, 1 ounce.

‡ Hyposulphite of soda, 5 ounces; distilled water, 5 ounces.

varnish is drained off, and the plate is warmed until the varnish is dry. This finishes the Negative; it is now ready for the Printing.

PRINTING copies is also effected by the light. The negative is placed in a frame, called the Printing frame, and a piece of prepared paper,* cut the right size, is put with it, the varnished side of the negative being next to the prepared side of the paper. The frame is closed and exposed to the light. The time may vary from a few minutes to a whole day, according to the weather and state of the negative. When the white parts appear slightly tinted this process is finished. They must then be kept in the dark.

The print appears of a chocolate tint, and needs *Toning*. But little light must be allowed while this is done. First wash the prints in water for about ten minutes, and then put them into the toning solution† in a glass or porcelain dish. Move them about until the chocolate colour becomes a dark purple or nearly black. Then remove and place them in water, but in the dark.

As with the Negatives, the prints need FIXING. They should be placed in the fixing solution,‡ and kept there for about twenty minutes, being moved about and turned over from time to time. Let them drain, and be put into clean water. The fixing must also be carried on in the dark.

* It is best to purchase permanent sensitive paper.

† Chloride of gold, 4 grains; acetate of soda, ¼ ounce; distilled water, 10 ounces.

‡ Hyposulphite of soda, 3 ounces; distilled water, 1 pint.

WASHING is now needed in an earthenware vessel, and plenty of water, the water being changed five or six times, draining the prints carefully each time. They should be left in the last water all night.

When washed they need to be dried in blotting paper, and may then be mounted with starch paste ;* gum is not suitable.

The above is a sketch of how a portrait is taken ; views and landscapes would be the same (with the variation in the camera named above), but the exposure would, of course, vary. The reader will see how many processes the picture has to go through before it is perfect and durable. A failure in any one of the operations might spoil all. The chemicals must be pure, and the greatest cleanliness must be observed throughout, each tray being used for one purpose only. Amateurs are often tempted to purchase the apparatus, but we fear often fail in its use from want of handiness and perseverance, or from not paying sufficient attention to all the details : their apparatus are often advertised for sale. There are, of course, exceptions, for some amateurs attain proficiency.

The DRY PLATE PROCESS differs from the above, in that the plate is used dry, and thus can be carried about more easily, a camera only being requisite, and the plates need not be developed for a long time afterwards. On a tour, views can be taken, and the plates be carefully kept until the return home. There are

* Mix the starch with cold water into a thick paste, then add hot water ; use it warm.

different dry plates to be purchased, ready prepared.

INSTANTANEOUS PHOTOGRAPHS are taken by using specially prepared plates, extra sensitive; and the lenses are called quick acting ones. The stop is either removed or the opening enlarged. The exposure is only a fractional part of a second. Some very curious results have been obtained by this means, such as the varied positions of the legs of a horse when galloping; some of the attitudes look ridiculous, though they are correct.

The attitudes have been proved to be true by taking pictures in rapid succession, and then mounting them as in the Zoetrope,* and on its being set in motion, the horse appears to be galloping.

There are still other processes by which a person in a railway carriage can take a view of the scenery he is passing even while the train is in motion. A camera can be made to shut up and look like a brown paper parcel or even a watch. Touch a spring and a portrait can be taken without a person having any idea of it.

THE USES OF PHOTOGRAPHY.

We are all familiar with Portraits, by which we are able, vividly, to call to mind the very features of many of our dear relatives and friends passed away from the earth.

Views of places and ancient monuments are the next most interesting objects. Who that has seen a

* See page 26.

photograph of the Arch of Titus has not looked with the deepest interest at the representation of the carrying away, as captives, some of God's ancient people the Jews (in which also the golden candlestick and table of the temple are conspicuous), after the destruction of Jerusalem by that general, not simply as a conqueror, but as the instrument used by God to punish His guilty people? With what awe should a Jew look upon that picture, when he remembers what called forth that severe punishment. And, if he has eyes to see, what joy it should awaken when he remembers that God, who has punished, has also foretold future gathering and blessing to His now scattered nation.

Perhaps the next most useful application of photography to be named is the way in which photographs are made available for ordinary printing. There is what is called PHOTO-LITHOGRAPHY, when the printing is from lithographic stones; and there is the system of PHOTO-ENGRAVING, which produces a plate with raised parts that can be printed at an ordinary printing press. In both systems the advantage is, that there is no copying by the eye, which is liable to be more or less inaccurate; but what the light prints in the photograph is exactly re-produced by the printing press.

Doubtless you will like to have some idea how this wonderful thing is accomplished. It must first be noticed that, in ordinary Lithography the part that prints is that which is bitten on to the surface of the stone. The stone is wetted, and then a roller covered

with ink is passed over the stone, but the ink attaches only to the part bitten, and, when the paper is applied, this is all that is printed. In copper-plate the part that prints is *dug out*, then filled with ink, the rest of the plate being wiped clean. In common, or letter-press printing the part that prints is *raised up*, and is the only part that is inked. In stereotyping, a mould of the type, or of an engraving on wood, has to be made first in paper or in plaster of paris, and the melted metal poured on to the mould; or the mould can be placed in a battery and a copy of it deposited in copper, called Electrotyping.

Now the question is, How can anything like this be produced by photography? What is really produced, and all that is needed for letter-press printing, as will be seen by the above, is a correct *mould* into which metal can be poured, or copper deposited. A solution is made of gelatine and bichromate of potash. This is spread while warm upon a steel plate, and allowed to dry in the dark. A negative of what is wanted is produced, and the prepared plate placed with this negative. The light causes the chromic acid to be reduced to sesquioxide of chromium, and the oxygen converts the gelatine into an insoluble substance. If the surface is now wetted, the parts not affected by the light swell up, leaving the other parts at their former level. *This gives the mould.* There are other processes, but the principle is similar.

Photography is not restricted to terrestrial objects: beautiful photographs have been taken of the moon, and of the corona of the sun seen at an eclipse. The

corona, or crown, resembles flames issuing all round the sun. Portions of the heavens also have been photographed, shewing the exact apparent position of the stars in their relation one to another. The spectrum also of the sun and stars has been photographed.

Photographs, as is generally known, can be enlarged. They can also be reduced in size till they are very small, called MICRO-PHOTOGRAPHY. This was turned to use during the Franco-Prussian War in 1870–1, when Paris was besieged. Despatches containing many thousands of words were reduced to the size of two inches by one. The collodion film was taken from the glass plate, rolled up and inserted in a quill and fastened to the tail of a carrier pigeon. When it reached Paris the film was placed in an enlarging lantern and thrown on to a screen, copied off, and published.

Another use made of photography is to register *the rise or fall of the barometer and thermometer.* This can be carried on both night and day with little attention. The mode of working it resembles more the printing we have described than the taking a picture. The following will give some idea of how this can be done. At the top of the tube of a barometer or thermometer, there is always a vacant space above the mercury. A light is placed before the tube, and behind the tube is a plate shutting out the light except through a slit corresponding with this column of mercury. Behind this is a roll of sensitive paper, which is made to unroll by clock-work, and the light prints the *size* of the vacant space on the paper. If the

mercury rises of course the vacant space is shorter, and this is seen on the paper; if the mercury falls, it is larger.

We have seen how photography can permanently copy things on earth, and things in the heavens; it can also copy things *in the sea* by means of the electric light.

From all this we may gather, in some small degree, a knowledge of what wonderful things there are bound up in a ray of light; it is not simply light, not simply light and colour, but there is that also which acts chemically. All this is supposed to be in the vibrations of some unknown medium, called luminous ether! Does it not stamp upon it "the handiwork of God" in a marvellous way?

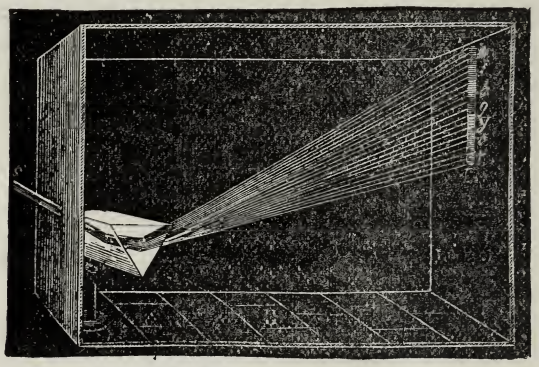
EVENING VIII.

COLOUR.

COLOUR is one of the most wonderful things in nature. We commonly say that a ribbon is red or blue, white or black, and this is right enough, because people know what is meant by what we say; but if we place four pieces of ribbon, or anything else, of different colours on a table, and wait till it is nearly dark—so dark that we can just see that there are four pieces of ribbon—we then cannot tell which is red and which is blue, and scarcely which is black and which is white. It will be said the reason is because it is too dark. True, but we can see that the ribbons are there, how is it we cannot see what colours they are? Well, strange as it may seem, we have to learn that *the colours are in the light*; and therefore the reason why we cannot see the colours is, because if there is no light *the colours are not there.* If we see them in a coloured light we cannot distinguish the colours, and not well even in gas light.

This needs an explanation, and we must now try to discover the source and nature of colour. We have all, I suppose, seen a rainbow in the heavens: how is this caused? We know that the rainbow is seen when rain is falling and the sun is shining at the same time. The light of the sun may be said to be white, and the drops of rain are white, and yet what beautiful colours we see in the rainbow: whence are the colours?

An experiment will help us to understand this; it was first tried by Sir Isaac Newton. When the sun is shining into a room, if we shut the shutters, a small hole made in the shutters will let in a ray of light; let this ray of light fall upon a glass prism, and on a sheet of paper all the colours of the rainbow will be seen, and the colours will be in the same order as in the rainbow in the heavens. They can often be well seen without darkening the room, and even by a three-sided plain glass lustre of a chandelier.

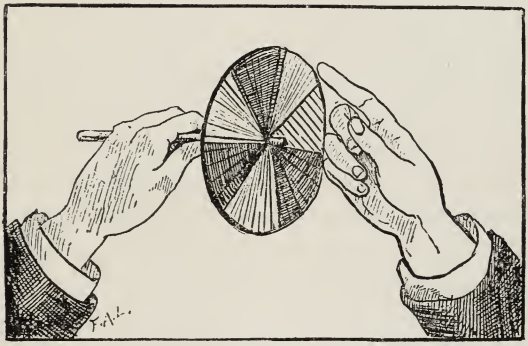


S is the ray of light, and this, if there had been no prism in the way, would have fallen on to the floor By the prism the ray is refracted twice, dissected as we might say, and spread out into rays shewing the colours: red, orange, yellow, green, blue, indigo, and violet. If one of the colours is passed through another prism, it does not further divide.

There are various ways in which the seven colours can be re-united, and then they form again a white light

only, which proves that all these colours are simply a ray of *white* light broken up.

To effect this a second prism may be placed near the first, but reversed in position, one of the edges being upward ; or a double convex lens, like a reading glass, may be placed so as to embrace all the colours, and in the focus of the glass there will be white light only. The same may be proved by the seven colours being accurately painted on a disc, and revolved rapidly ; the result is white, but not nearly as pure a white as with light only, for the paints are not so true to the colours.



To return to the rainbow, the question remains, how are the colours produced in a rainbow ? There are not prisms hanging in the air, by which the rays are dispersed. True, but we must first consider what shape the rain drops are. When we look at the rain it appears to fall in *lines*, and it is by lines that rain is generally shewn in a picture. We have already seen that anything whirled round rapidly appears as a

wheel ; so it is with the rain, the drops fall so rapidly that, before the sight of one has died away, another has followed, until the rain appears to fall in *lines*.

Without doubt rain falls in small spheres. After a shower we see it thus hanging on trees, &c., and then if we watch we see the drops fall as spheres. The question then returns, will a sphere also give us all the colours of the rainbow ? If when the sun is shining we hold a globular water bottle full of water in the rays we are able to see some of the colours ; for instance the two extreme colours are seen ; the red on one side, and the violet on the other.

From this we gather that all the colours of the rainbow are produced by the sun shining upon round drops of rain, and are then refracted to the eye at different angles, for each colour has its own refrangibility or degree of refraction.

It sometimes happens that there are two rainbows seen at the same time. In the higher one the rays of light strike the drops at the *bottom*, are refracted, and then reflected inside the drop, and again refracted in passing through the air to the eye. In the lower bow the rays of light enter the drops at the *top*, and leave at the bottom. See frontispiece.

In the upper rainbow the violet rays are at the top, and the red at the bottom ; but in the lower the red are at the top, and the violet at the bottom. At times even a third bow has been seen.

The same colours are sometimes visible at sea when waves are thrown up into a fine spray, if the spectator is between the sun and the spray.

From the above it is proved that all the colours are bound up in a ray of white light. It is generally held that there are only three fundamental colours, and that the others are formed by combinations of these. Sir D. Brewster supposed the fundamental colours to be red, yellow, and blue, the other colours being formed by overlapping. Any one accustomed to the mixing of colours for painting knows that red and yellow produce orange ; yellow and blue, green ; and blue and red, violet ; and all this seems to confirm Sir D. Brewster's conclusion. But others contend that the three primary colours are red, green, and blue, and that the other colours are formed by the overlapping of these ; and say that the mixing of pigments used in painting does not correspond with the mingling of coloured light. Thus, though in paints blue and yellow produce green, in light, blue and yellow produce a sort of white. But why need we conclude that any particular colours are *primary*?

A simple experiment may be made that will give some idea of how the effect of mixing two paints together is different from the overlapping of two rays of coloured light. Cut three discs of cardboard, of say one and a half inch in diameter, colour one with ultramarine blue, and another with chrome yellow. Then mix the two paints together, and cover the third ; this will be a green. Place the blue and yellow discs on the table facing the light, about seven inches apart. Take a piece of glass and hold it up between the discs. Now by standing up and looking through the glass a reflection of one of the discs may be seen overlapping

the other. The colour produced by the combination of the two will not be a green like the mixed paints, but a greyish or pinkish white. If the yellow seems to swamp the blue, the yellow must be shaded somewhat. A disc cut out of yellow paper, and another from blue paper will shew the same thing.

We must now consider how it is that some things appear blue, and others red, &c. The same light shines upon them all, how is it then if all colour is in the light that all do not appear as one colour? We ought to be very thankful that everything does not appear in the same dress. What a loss it would have been, and how impossible to conceive of any colour that would have been agreeable for everything, for the eye would soon have been weary of seeing nothing but one colour. God has in His wisdom prevented this, and has given in the vegetable world and elsewhere a great variety of beautiful colours, with varying shades of brightness and of delicate softness, which the best painter can but imperfectly imitate, though one man is said to have painted grapes so naturally that birds were deceived and pecked at them.

The theory about colour is, that an article that appears red absorbs all the parts of a ray of light, *except the red*, this it reflects, and so we say it is red. And so of any other colour. Some things may reflect parts of different colours, and thus supply the numberless tints and shades which are different from any colour visible in the rainbow. If an article *reflects* all the coloured rays of light, we say it is *white*; and if it *absorbs* all these rays we say it is *black*.

THE UNSEEN PARTS OF A RAY OF LIGHT.

In looking at the various colours shewn in a ray of light divided by a prism, we might naturally suppose that we saw all the particles of that ray; but this is not so, for it has been proved that there are invisible parts of the ray far beyond the red at the one end and beyond the violet at the other. Under ordinary circumstances these portions are invisible, but by using certain means they can be made manifest.

Experiments were tried to discover whether the heat of the sun's rays was the same in the differently coloured parts of a ray, and the heat was found to be quite different. By moving a delicate thermometer along the spectrum, and reckoning the greatest heat as 100, it was found that the blue part shewed no heat; on entering the green the thermometer shewed 2; and on entering the red it rose at once to 21, and at the end of the visible red it rose to 45, and in the invisible part it rose to 100. Tyndall made a sort of map of the heat of the rays; it was like a hill, rising gradually from the blue till the red was reached, and then shot up suddenly like a mountain. The above results were obtained from the electric light with a lantern and lenses of rock salt, which cut off less heat than glass In a spectrum from the sun's rays the elevation at the red portion was not so steep, a portion of the heat was supposed to be absorbed by the aqueous vapours in the atmosphere.

The invisible portion of a ray of light was thus proved to exist, and by further experiments it was

shewn that the heat from thence could be condensed by a lens so as to set fire to gunpowder or gun cotton.

The wonders of a ray of light are not yet exhausted. We have glanced at the invisible portion at the red end of the spectrum, but at the violet end there is another invisible portion, with wonderful properties. It is called *Actinism*, from the Greek *aktin*, a ray ; but this does not explain its properties. It is the portion of a ray of light that acts *chemically*, and which is so active in photography.

If a sensitive photographic plate—say of iodide of silver—is passed along the spectrum of a ray of light, commencing at the portion beyond the visible red there is no effect produced, nor as we pass through the red, orange, yellow, green, blue ; but in the indigo and continuing beyond the violet, the plate is affected.

It will thus be seen that at the red end of the spectrum both light and heat are obtained, and at the violet end the indigo and violet give both light and actinic effects ; the heat at the one end and the actinism at the other extend far beyond the visible portion.

A ray of light may be divided into three parts ; at one end it acts chemically ; in the centre it gives light and the various colours ; and at the other end it gives heat. The three parts overlap each other.

Surely the mighty powers of God are manifested in a ray of light ! There is beauty and power combined, extending to all that has yet been discovered to be comprised in it, even in so small a compass as can pass through a tiny hole in a shutter.

EVENING IX.

COLOUR BY THIN FILMS, COLOUR BY HEAT, COMPLEMENTARY COLOURS, COLOURED SHADOWS.

THERE are still some curious ways of shewing colours, which are much easier to produce than to explain the "why and because" of.

For instance, take a small black tray or hand-waiter and pour water into it to the depth of about half an inch. Then dip a piece of stick into turpentine, and let one or two drops of it fall into the water. It at once spreads itself into a thin film on the surface, and shews beautiful colours.

Anyone who has blown a common soap bubble must have noticed the fine colours that are seen round the bubble, but more beautiful effects can be produced by mixing glycerine with castile soap and water. With this mixture small rings attached to a handle will take up a film of soap-suds that can be examined for an hour. The rings must be soaped all round to make the mixture adhere properly. Very beautiful colours are the result.

Colours may also be seen between two small pieces of plate glass if rubbed together so as for one to come in close contact with the other. There are also what are called *Newton's Rings*, which are produced by a thin film of air between two glasses. A glass slightly convex, such as the *cover* on a microscope-slide, is pressed against a flat piece of glass. Almost the same

effect may be produced by having two glass discs (one a quarter of an inch in thickness), and putting between them, near the edge, a ring of gold leaf, then by pressing the glasses closely together beautiful coloured rings will be seen.

This latter experiment may be used with the optical lantern, and the colours thrown on to a screen.

Now one is naturally curious to know what is the cause of colours being seen in the above experiments. The first thing to notice is that the films that shew the colours must be very thin. The supposition is that the waves of light reflected by the upper and lower surfaces of the films interfere with each other, and that this interference causes in some way the colours to be seen.

Newton attempted to measure the thickness of these thin films of air, and found that the most perfect series of colours were produced by films of the following thicknesses, though colours could be seen with both thinner and thicker films.

NEWTON'S SCALE OF COLOURS.—The inch is divided into a million parts, and then, for what is called the second order of thicknesses :—

Violet	took	11.17	of such parts.
Indigo	,,	12.82	,,
Blue	,,	14.00	,,
Green	,,	15.12	,,
Yellow	,,	16.29	,,
Orange	,,	17.22	,,
Red	,,	18.20	,,
Dark red	,,	19.67	,,

The soap bubble is on the same principle. It is its excessive thinness that causes the colours to be seen, and we can easily imagine that some parts of it may be thicker than others. Thin films of water will also make colours visible.

IRIDESCENT GLASS vessels may often be seen in the shop windows. They shew various colours on the same vessel. These colours are produced by very thin transparent films on the body of the vessel.

COLOUR BY HEAT.

There are several substances that begin to shew colour by oxidation when they are heated, and the colour varies as the heat is increased. We will confine our attention principally to steel, as this not only shews the colours, but the changes in its colour have been turned to useful purposes. If a piece of steel is made bright and is then laid upon a sheet of iron with a gas or lamp flame beneath it, colour will soon make its appearance, and will change as the heat is increased. The use that is made of this is to *temper* the steel. After steel has been hardened, by making it red hot and suddenly cooling it in water, it is too hard for many purposes, and has to be tempered for the particular purpose for which it is required. Small articles are tempered before they have become cold, and are then suddenly cooled. As it may be useful for reference, the principal colours are named, together with their uses; but different qualities of steel require different degrees of heat.

Fahrenheit. DEGREES.	*Colour.*	*Use.*
430	Very pale straw	Light turning tools, lancets.
450	Light straw	Wood engraving tools, razors.
470	Dark straw	Boring tools, penknives.
490	Darker straw	Cold chisels, scissors.
500	Brownish yellow	Hatchets, plane irons.
510	Brown	Twist drills, pocket-knives
520	Very pale purple	Table cutlery
530	Light purple	Swords, watch springs.
540	Purple	Gimlets, needles
550	Dark purple	Springs.
560	Dark blue	Fine saws, augers.
570	Blue	Small saws.
600	Pale blue	Hand and pit-saws.

The colours are afterwards removed by polishing ; but in watch and clock hands the beautiful blue colour is allowed to remain. From 530° to 600° is used for all articles requiring elasticity.

Colour has also been produced on coins. If a silver coin is cleaned, then rubbed a little on sand-paper (so as to roughen the parts that are raised) and then placed on a hot plate, over a gas stove, the rough parts will exhibit colours, and settle into a bronze. Without any roughing, if an old coin, in which the inscription has become partly illegible, is cleaned and heated as explained above, the inscription will be able to be read by the otherwise invisible letters shewing themselves. The parts where the die has struck the coin and compressed the metal do not oxidate so quickly as the elevated parts, which are the least compressed, thus making the letters visible. Very old much-worn coins are thus deciphered.

COMPLEMENTARY COLOURS.

These are so called because various colours are said to complement or 'fill up' other colours. Any two colours that produce a near approach to white or neutrality are called complementary.

Thus Red and Green,
Orange and Blue,
Yellow and Violet

are called complementary colours. When the eye has become weary by looking long at one of these colours, it then sees the colour that is complementary. Mr. Ackroyd says that after he had been looking for half an hour at the orange-red light of a building on fire, on casting his eye upward the moon appeared a decided *blue*.

Any one can prove the question of complementary colours by cutting out a disc of card and painting it blue. If he looks stedfastly at this for half a minute and then looks at a white sheet of paper he will see an *orange* disc. If he looked at red he would see a green ; so of yellow and violet.

These transformations have often been produced in advertisements as something wonderful, but they are quite natural. The reason appears to be that when the eye has long gazed at one colour, it then absorbs that colour when looking at white, and sees the colour most opposed to it, or what is called its complement.

Bright complementary colours are generally avoided in articles of dress : the great contrast would not be pleasing to the eye.

COLOURED SHADOWS.

A very curious effect is produced when shadows are seen of the same object by different coloured lights. Thus if the shadow of an object is thrown on to a white ground by both a red light and a white light, the shadow by the white light will look red, and the shadow by the red light will look green. It will be seen that these colours are complementary. The explanation is that the eye is surfeited as it were with the red colour on both sides of the shadow, and then the shadow looks green; and the shadow by the white is swamped by the red.

A similar but modified effect may be seen in the shadow of a person on a white pavement by the yellow light of gas and the white light of the moon.

EVENING X.

POLARISATION OF LIGHT, THE SPECTROSCOPE.

IT has been found that some substances divide a ray of light into two branches. Thus Huyghens found that Iceland spar, except in one position divided a ray of light into two rays of equal intensity. On letting these rays pass through another portion of the same material, their intensity was not the same; and on turning the second spar one of the rays vanished altogether. On looking at a dot on a sheet of paper through the spar, *two* dots will be seen. If we look straight down through the spar, and if we turn it round, one dot will appear to move round the other.

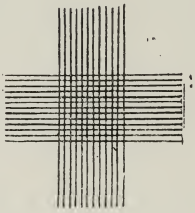
This is called Polarisation, though the name does not seem to be very appropriate. It appears to have gained this appellation from the fact that as a magnet will turn the poles of a number of magnetic needles in one direction, so the vibration of a ray of light will be confined to one *plane* if polarised.

One of the rays through the Iceland spar is refracted according to the ordinary law for transparent bodies, and is, therefore, called the *ordinary ray*; the other is different, and is called the *extraordinary ray*; through some substances both the rays are 'extraordinary.' As we have seen Iceland spar allows both the rays to pass through; but if the spar is cut in a particular way and rejoined by Canada balsam—then

called a NICOL PRISM—the ordinary ray is got rid of, and the extraordinary ray can be dealt with.

In the polarisation of light two things are needed, an *analyser* and a *polariser*; a Nicol prism, tourmaline, or herapathite* can be used for either.

When these are applied to a microscope, by looking through them, a few bars or strokes are seen; but if the polariser is turned round gently in one part of the revolution the light is lost. This may be illustrated in this way. If we suppose a ray of ordinary light to be caused by vibrations in all directions and in various forms, and a polarised ray to be caused by vibrations in one plane only, this would be able to pass through a



series of bars in the analyser, and also in the polariser *if the bars were in the same direction.* If the second series of bars were partially turned some vibrations and some light would still be able to pass; but when the bars of the polariser lie directly across the bars of the analyser *darkness* is the result, no light can pass.

This is remarkable, seeing that both the analyser

* This is the sulphate of Iodo-quinine, and a sort of artificial tourmaline. It was first prepared by the Chemist Herapath.

and the polariser are transparent, and yet no light can pass. Perhaps we yet know so little of the actual nature of light that no one can really be certain as to the cause of darkness; but the above illustration shews how it is supposed to be; a piece of card could pass between the lines lying horizontally, and also between those placed vertically, except where they cross, and there it could not pass.

In a microscope the analyser is fixed next the eye, and the polariser *below* the stage, so that objects can be placed between them.

Polarised light shews beautiful colours where natural light does not. Thus, if a few grains of castor or finely crushed sugar are placed on the stage of the microscope, the crystals seen in the polarised light are most beautiful and the colours splendid.

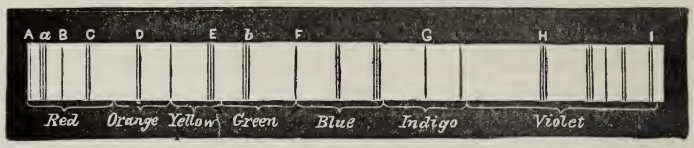
Many other things are suitable objects to be viewed in a polarised light, such as scales of fishes, sections of hair, horn, egg-shells, starch grains, fibres of cotton and flax, hairs and scales from leaves, scraps of sponge, &c.

Bundles of glass may be used for both analyser and polariser if placed at a proper angle to a ray of light. For crown glass the polarising angle is 56° 45'.* Polarisation may be produced by reflection or refraction, and by one of the double rays in Iceland spar being absorbed.

* Sir David Brewster's law is that "the index of refraction is the tangent of the angle of polarisation."

THE SPECTROSCOPE.

There are still further wonders discovered in a ray of light. We have seen that it can be divided into seven different colours, though some of these may be caused by over-lapping, for they seem to merge one into the other. Now besides these colours there are also *lines*, which cross the spectrum or band of colours;

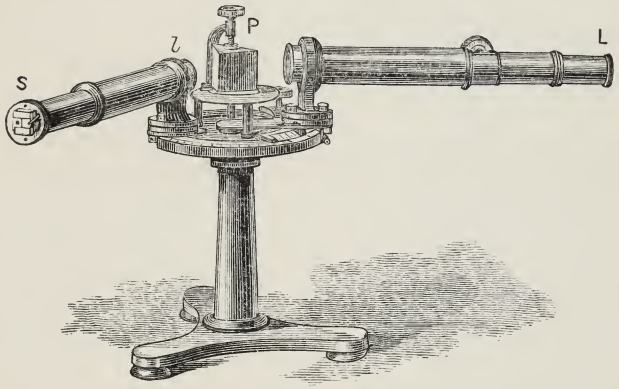


but these dark lines do not coincide with the colours. It will be seen that the lines called A, B, C are in the red; D, a double line, in the orange; E, three lines, in the yellow; F, between the green and blue; G, in the indigo; H, three lines, and I, two lines, in the violet.

These lines are what appear in a ray of light from the sun; but they are only a few of the principal ones, for there are in reality thousands of fine lines. Lines were discovered by Wollaston, but were more minutely examined by a German optician, of Munich, named Frauenhofer, about A.D. 1814, and are called FRAUENHOFER LINES. The places of the lines A to I are considered as fixed points in the spectrum, so that if a person examines anything with the spectroscope he can describe *where* its lines in the spectrum are to be found. Dr. Kirchhoff made a more detailed map of

the lines in the solar spectrum, so that comparison can be made more exactly than by the lines of Frauenhofer.

But I must describe the spectroscope. It derives its name from 'spectrum,' something seen, and *skopeo*, to view. It is an instrument by which to examine the spectrum presented by any particular substance through which a light is shining.



It is formed of two small telescopes. One *(l)* is made a fixture: its eye-piece is removed, and a piece of brass (S) adjusted, in which is a fine slit, with a screw to make the slit wider or narrower. At the other end there is an object glass. Beyond this is a prism (P) on a pivot so that it can be turned. In some instruments there are several prisms. The other telescope (L) is moveable in order to be able to bring it in the right direction towards the prism.

Anything to be examined is placed before the slit

with a strong light behind it. The spectrum is formed on the prism, and is seen by looking through the other telescope.

Frauenhofer, in examining the lines from the sun, tried them with different prisms, and found the lines were always the same ; so this proved that the lines were not caused by the prisms. He then tried reflected light (by the planets or the moon, or a cloud), and found the lines were again the same. He then tried them by the light of different stars, and now he found a difference ; none were exactly like those given by light from the sun. This proved that the lines were not caused by the atmosphere, or the space beyond ; there must be some difference in the light itself.

He first proceeded to make an accurate map of the lines shewn by the sun. He then tried the light of a candle. This also gave some dark lines, but he was surprised to find two *bright* lines near the dark lines he called D. This was afterwards judged to be caused by sodium in the candle flame.

Dr. Kirchhoff by the use of an instrument of greater power was enabled to examine at the same time a spectrum of the sun, and a sodium vapour with a Bunsen's lamp, and now found that the bright lines fell exactly on the D black lines of the sun. He then tried the full power of the sun, and now could plainly see the D dark lines *in* the sodium-coloured bands.

Now at first sight it would seem that there could be no connection between the two *dark* lines D of a ray from the sun, and the two bright *yellow* lines of sodium ; but the coincident lines are thought to prove

that there is sodium in the sun or in its atmosphere. It has been found that the light from *burning* sodium produces a bright yellow band at D; but if light passes through the *vapour* of sodium it produces dark lines at the same spot.

Thus the dark lines seen in the solar spectrum are held to prove that the light passes through some medium in the atmosphere of the sun that *absorbs* the rays of light that would otherwise come to us. If so, in the solar spectrum we do not get all the tints of colour; many of them being absorbed, and in these places dark lines appear. In the spectrum of iron there are no less than 450 bright lines, and in the spectrum of the sun dark lines exactly correspond to every one of them, strong lines corresponding to strong lines, and faint lines to faint lines.

The use of the Spectroscope is said to prove that in the sun or its atmosphere there exist aluminium, barium, calcium, chromium, cobalt, copper, hydrogen, iron, magnesium, manganese, nickel, sodium, titanium, &c.

At a total eclipse of the sun Professor Young saw the solar spectrum vanish; but in place of the rainbow-tinted riband, crossed by thousands of dark lines, there appeared a riband of *rainbow-tinted lines*, thousands in number, and in all degrees of thickness; hundreds of red lines, and then in order hundreds of yellow, green, indigo, and violet lines, like coloured cross-threads on a *black riband*, only infinitely more beautiful!

The Spectroscope led to what is called SPECTRUM

ANALYSIS. As sodium always shews two bright lines where D stands in the sun's spectrum, if I had a substance that I could not recognise, and I examined it in the spectroscope, and found two yellow lines where D stands, I should know that it was sodium, or that sodium was present.

For though it is believed that every element has its own particular spectrum, yet if two or three of them are mixed, they do not interfere with one another; but the two or three peculiar markings would be visible, and very minute portions have been proved to shew themselves in the spectrum. Thus it is declared that the 180-millionth part of a grain of sodium would be detected.

New elements have been discovered by means of the Spectroscope. In examining stray things, certain fresh marks have been noticed, which further investigations have proved to belong to elements hitherto unknown.

Thus Thallium was discovered by Mr. Crookes in examining some refuse from the gas works. The lines struck him as unusual, and on further research the thing examined was discovered to be an unknown metal, and it was named Thallium from the Greek word *thallos*, a green bud. It shews a bright green band near E.

A few characteristics of other things may be named. C, F, G, characterise Hydrogen; D, Sodium, as we have seen; E, Iron; H, Aluminium; C, Magnesium.

We have said that the lines seen in a spectrum of

the sun's rays are proved not to be due to our atmosphere, and in the main this is true ; but repeated observations have led to the belief that some of the faint lines are due to the atmosphere, for they are fainter when seen on the top of a mountain, and are not seen at all on some occasions.

It will easily be conceived that the Spectroscope can be usefully employed in detecting adulterations, as the smallest particles of some substances invariably make their presence known.

Some astronomers believe that they also learn by the spectroscope that some of the stars are receding from us, and others are approaching, by the displacement of certain lines in the spectrum they give.

The instrument is comparatively new, and there may be yet different work in store for it, though it will be seen from the above that already much has been accomplished with it, and that it is useful as well as interesting.

How wonderful that by various bright and dark lines, different substances should be distinguishable ! And who but the Almighty could have formed such marvellously delicate lines in a ray of light ?

EVENING XI.

THE COLOUR OF ANIMALS, COLOUR BLINDNESS.

IT is very interesting to examine the varied colours given by God to animals, corresponding to the places in which they live, or in which they seek their food, so as to avoid too great an exposure to their enemies.

Perhaps the most familiar example is the green fly on the leaves of plants. Many caterpillars are also green like the leaves on which they feed; others that rest on the bark or on twigs are brown.

Some moths settle on brickwork, and cannot easily be distinguished: others are like the stone walls on which they rest. Slugs will roll themselves up into balls, and drop on to the gravel walks, when it is very difficult to distinguish them from small stones.

With some creatures it is not simply their colour that hides them, but they are marked exactly like the leaves on which they feed; others are marked like the boughs of the trees they inhabit, and are in shape like leaves.

It is similar with fishes that rest on the sand, as flounders, skate, and sole: it is only a practised eye that can distinguish them from the sand. Those which swim near the surface are mostly of a dark blue or green shade above, and white beneath. Others are very like the sea weeds in which they congregate.

Mr. A. R. Wallace gives a good description of the

leaf-butterfly of India. It is large and handsome, of a deep bluish colour, with a broad orange band across the wings. It is thus a conspicuous object when on the wing, but it flies very quickly, and is difficult to capture. When it settles it is exceedingly difficult to discover. Mr. Wallace says "To render the disguise effective, it is necessary that the insect should assume the position of a leaf [which it much resembles in shape], and this it does most perfectly. It always settles on an upright twig or branch, holding on by its fore legs, while its body (concealed between the lower margins of the wings) rests against the stem, which the extremity of the tail, representing the stalk, just touches. . . . . the creature seems to have an instinct which leads it to prefer to rest among dead or decaying leaves. . . . .You see this gay butterfly careering along the forest path, and suddenly rest upon a shrub not three yards from you. Approaching carefully, you look for it in vain, and you may often have to touch the branches before it will dart out from under your very eyes. Again you follow it, and mark the very branch on which it has seemed to rest; but in vain you creep forward, and scan minutely every twig and leaf. You see nothing but foliage—some green, some brown and decaying, till the insect again starts forth, and you have been actually gazing upon it without being able to see any difference between it and the surrounding leaves."

There are other creatures that so closely resemble sticks that they cannot be distinguished except by feeling that they are soft.

This wonderful protection given to animals by their colour is seen all over the world. A traveller in the Sahara says, "In the desert, where neither trees, bush-wood, nor even undulations of the surface afford the slightest protection against its foes, a modification of colour which shall assimilate an animal to that of the surrounding country is absolutely necessary. Hence without exception the upper plumage of every bird, whether lark, chat, sylvian, or sand-grouse, and also the fur of all the smaller mammals, and the skin of all the snakes and lizards, is of one uniform isabelline or sand colour."

In the Arctic regions also bears are white to correspond with the snow and ice, though brown or black everywhere else. The Arctic fox, Alpine hare and the ermine change their colour to white in the winter.

Of course there are many other things that give protection, besides colour and resemblance. There are, for instance, some caterpillars that birds will not eat. If they take one into their bills they drop it immediately as if too nasty. Other creatures have stings or some such means of defending themselves, and need not the same protection as those without weapons of defence.

The chameleon ought perhaps to be referred to, though it is not known that it assumes its different colour for protection in any way: it was at one time supposed that its changes were regulated by whatever surrounded it. Dr. Shaw, however, found the natural colour of those brought to this country was a bluish ash, and changed to a green, and sometimes yellowish

hue, spotted unequally with red. "If the animal be exposed to a full sunshine, the unilluminated side generally appears, within the space of some minutes, of a pale yellow, with large rounded patches or spots of red brown. On reversing the situation of the animal the same change takes place in an opposite direction, the side which was before in the shade now becoming either brown or ash colour, while the other side becomes yellow and red ; but these changes are subject to much variation, both as to intensity of colour and disposition of spots." Naturalists are not at all agreed as to how the changes are produced. Some believe there are layers of membranous colours in the skin, which the animal has the power of shewing at the surface, singly or in combination.

Who can fail to see the finger of God in all these provisions made for the security of creatures, even for the most minute or apparently insignificant ?

COLOUR BLINDNESS.

It is a curious fact that many persons whose eyesight is comparatively good are blind to the difference of some or all of the various colours. This is very inconvenient for them, and it can be readily understood how dangerous it would be for a person thus deficient to hold some situations, such as an engine driver on a railway ; for perhaps he could not tell the difference between a green light and a red one.

Another curious thing is that the people who are thus affected seem quite unconscious of it. They hear

people calling one thing red, another blue, etc., and soon learn to call them by the same names, without really seeing the difference. That many persons are thus affected has been proved by the spreading out on a table a number of skeins of coloured wool and asking them to sort them, or to pick out all the reds, blues, greens, etc., when it has been found that they put very different colours together, because they could not see any difference.

Where there is any suspicion of a lad being colour-blind, it ought to be tested before he is put to any business. Various anecdotes shew how important this is. For instance, one of the government clerks was thus afflicted ; and having to use at times red, blue, and black ink, and the bottles being the same shape, he was sadly puzzled. But he tried to keep the bottles always in the same position, and by that means got on pretty well. There were, however, some youngsters in the office, who mischievously changed the order of the bottles, and then the poor clerk might be seen presenting a letter for signature *partly* written in red ink. He was removed to another department, where his work was to tick certain entries in black, and others in red ; but here he so completely failed to keep the inks distinct that he had to be dismissed.

Sometimes all in a family are thus affected. In one case three brothers were all colour-blind. One was a painter, but he could never mix his own paints ; another was in an upholsterer's business, but on one occasion tried to persuade an old lady to purchase a

red sofa to match some *green* chairs : he had eventually to become a packer. The other could only fill a menial office.

A clerk in a post office was frequently found wrong in his money, and it was discovered that he had been selling the stamps incorrectly, because he could not distinguish their different colours.

These facts prove how necessary it is to ascertain whether a young person is colour-blind before choosing a business.

Colour-blindness is often called DALTONISM, from a chemist named Dalton, who was thus afflicted. He was a member of the Society of Friends, and yet he would walk in the street in a bright scarlet robe, belonging to him because he was Doctor of Civil Law, and when spoken to about it, said it was the same colour as some evergreens in a window. The lining of the robe was pink silk, and this he thought was like the blue sky.

It is to be feared that in times gone by, many accidents at sea and on land have been caused by persons being colour-blind, before it was discovered that this failing was so general. In later years the Nautical Department of the Board of Trade, and Railway officials, have examined the candidates as to colour-blindness.

We have spoken of the curious fact that people who are colour-blind are unconscious of it, and indeed may grow up to mature age before the fact is discovered. It was so with Dalton. He was examining the blossom of a *geranium zonale* with its violet petals,

by candlelight, when the petals appeared to have changed their colour since he saw them in daylight. He called attention to their being *red* by candlelight, and *blue* by daylight; but those to whom he spoke assured him that they had not changed, but were *violet* still. This awakened him to the fact that there was some strange deficiency in his eyesight.

Professor Delbœuf of Liége found out that his eyesight was defective earlier. When a boy, he declared that the lips and rosy cheeks of his companions were *blue*. His companions roared out, "Blue! you mean *red*." He was staggered; but when he got home and repeated the circumstance, he was assured that they really were red. Since he became professor he has studied more carefully the defect. He examined with a friend a spectrum caused by platinum, which is not very different from that of the sun. The professor could only distinguish two colours, which he called blue and yellow. In yellow he included green, yellow, orange and red.

M. Delbœuf then tried experiments with different thicknesses of a solution of purple *fuchsine*, and to his gratification he could then see colours he had never seen before. If it did not make his eyesight perfect, it revealed many beautiful colours, instead of seeing three or four as the same. He could now see the beauties of nature, and could distinguish the coloured fruit on a tree from the leaves.

Other affected persons tried the same purple solution, and they also could distinguish colours they had confounded before. Some required a greater thick-

ness of the solution than others, so he contrived a sort of wedge-shaped bottle, and by moving this before the eye, the proper thickness of the medium for each was discovered.

Further experiments were tried by persons with normal eyesight looking through a *green* solution, and then it was found that they became for the moment colour-blind.

It is hoped that by means of purple-coloured glasses many thus affected will be able to distinguish the different colours and join Professor Delbœuf in his admiration of the beauties of nature, which he so much enjoys after a long period of colour-blindness, and perhaps be able to follow useful employments from which they were formerly debarred.

And it is to be hoped that, as they view the works of the Great Creator, their thoughts may rise to Him who has thus beautifully clothed nature with its thousands of tints. If a sight of these colours for the first time causes such enchantment as was expressed by the Professor, should we who have always seen them be indifferent to their loveliness, and treat them as common things? They shew the handiwork of a beneficent and loving Creator.

CONCLUSION.

WHAT multitudes of wonders there are in a ray of light! We do not profess to have even looked at them all, much less understood and explained their mysteries; but the contemplation of them in however small a degree should raise our thoughts to their Creator, the Lord Jesus Christ, who is the true Light that came into this dark world, and should lead us to admire and bow to His wondrous work in redemption as well as in creation:

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